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THE TRACK-THROWING MACHINE AND CREW AT WORK.

VIEW OF CULEBRA FROM RESERVOIR, SHOWING ADMINISTRATION BUILDING TO LEFT, HOTEL TO RIGHT AND Y. M. C. A. CLUB HOUSE IN CENTER.

RECENT PROGRESS AT PANAMA.—[See page 358.]

THE AUDION.—II.*

A NEW RECEIVER FOR WIRELESS TELEGRAPHY.

BY LEE DE FOREST.

Concluded from Supplement No. 1665, page 350.

I have laid considerable stress upon the potential gradient or "variation" layers which exist near the surface of the electrodes when the external applied electromotive force is considerable, for the reason that their existence serves to play a very important rôle in the response of the audion to minute high-frequency oscillations.

If the velocity of negative ions is very large compared to that of the positive ions, the curve representing the distribution of electrical intensity between the two electrodes is represented by the following, which is typical.

When ions of both signs are present in the gas and when the electric field is so strong that most of the positive ions are driven from the anode and the negative ions from the cathode (the filament), we will have an excess of cations in front of the anode and of anions surrounding the cathode.

It is seen that the variation in potential lies chiefly in the thin layers of gas in front of the two electrodes. It is convenient to speak of these regions as the "variation" layers. As Thomson points out, in passing from the inside to the outside of the layer of ionized gas we have to pass across a layer of electricity. This will produce a discontinuity in the electrical intensity equal to 4π times the surface density of the electrification.

There may thus be a great difference between the electric intensity inside the layer and that just outside. The potential drop across the layer is proportional to the square of the current; the falls of potential at the positive and negative electrodes are proportional to the squares of velocities of the positive and negative ions; and the velocity of the ions is proportional to the electric force acting upon them.

These variation layers at the electrodes of the audion make still more striking its similarity with the cathode-ray tube. In the cathode tube a sudden drop in potential called the "anode fall of potential" occurs quite close to the anode; and in the layer called the Crookes dark space, or cathode dark space, there is a still greater fall in negative potential. But the voltages here are enormously higher than those in the audion. As the gas pressure in the cathode tube diminishes, the dark layer, or the cathode drop layer, becomes broader. $D = a + \beta\lambda$; that is, the width of the dark space is proportional to the mean free path of the molecules, beyond a certain distance a in front of the cathode. Schuster found that the thickness of the cathode drop layer increased slightly with the current passing through the gas; but Wehnelt found just the reverse. Both may be correct on different sides of some particular value of the current for which the width of this space is a minimum. This is interesting in view of the fact that there is a certain current flux across the gas of the audion for which the response of the Hertzian oscillations is maximum; supposing this response is maximum when the width of the variation layer around the filament is minimum.

Within the cathode layer there exist only negative ions, these being shot off from the cathode. Right outside of this, in the region called the "cathode glow," ionization of the gas from collisions with these negative ions begins, and the width of the cathode dark space is about the range of the "mean free path" of the ions.

If a similar state of affairs exists around the filament of the audion, and if this mean free path of the cations coincides with the excursion of the corpuscles during one half the oscillation period of the impressed Hertzian vibration, we might expect under these conditions a maximum effect of response to oscillation of the particular wave-frequency. Or a similar effect might be expected if the excursion in question is that of an ion from the cathode across the gas up to the layer surrounding the anode.

The extent to which the sensitiveness of the audion is governed by a very slight change in the heating current, or in the potential drop across it, seems to lend plausibility to such an explanation. And it has been shown that in conducting flames at atmospheric pressure, a negative ion acting under a potential gradient of 10 volts per millimeter would travel approximately 1 millimeter, or a commonly found distance between the electrodes in the audion, in 1/1,030,000 part of a second, which time-interval is of the order of one-half of the wave period of some of the longer oscillations used in wireless telegraphy. For reduced gas pressures the natural excursion of the ion would be more rapidly accomplished, but its velocity can be governed within wide limits by regulating the applied electromotive force. When we send more current through the filament we increase the potential difference between filament and anode as well as increase the heat. Both changes act to increase the ionic velocity.

In Humstedt's experiments where a cathode-ray tube was exposed to high-frequency oscillations, the width of the cathode drop layer, or dark space, diminished as the frequency of the oscillations increased; as if there might be some connection between the period and the time involved in the immigration across. And many facts observed in connection with the audion otherwise difficult to explain tempt one to suppose that here the degree of response is connected with the relation between the product of velocity of the ions by the distance between the electrodes and the period or half-period of the electrical oscillations received.

When the anode consists of two parallel plates instead of a cylinder there will be a maximum of positive electric density along their vertical edges. The more intense parts of the electric field will involve the larger number of ions, and on the anode these will generally be located at the vertical edges of the parallel plates, provided these are not too far from the filament.

With this type of anode a peculiar and sudden inflection point in the current-flux diagram, as the heating current is gradually increased or decreased, is noticed. The flux goes on increasing, then suddenly drops back to a lesser value; at the same time a click is heard in the telephone in the B circuit. Then as the heating current is still further increased the B flux is again increased. These same cusp points in the curve are obtained if the A circuit be kept constant and the B voltage is increased instead.

Similarly, a click is heard when the flux current is being reduced from a higher value, only the location of the cusp on the curve of decreasing current is not coincident with but lags behind that observed when B is being increased. This second cusp point shows a sudden *increase* in the flux current, when the critical point is reached, to a value previously passed through. Naturally the sharpness of these cusp points can be smoothed out or quite obliterated by putting impedance in the B circuit in series with the telephone.

The diagram (Fig. 9) shows the relative magnitude of these sudden alterations in the flux current obtained with a certain sample audion, and also the decided hysteresis effect, showing how the actual B current lags behind the increasing or decreasing electric field which produces it. This hysteresis effect is very like that obtained when the molecular structure of iron is altered under a changing magnetic field. Doubtless it is here due to a reluctance of the ions to accommodate their paths and velocities to the impelling electric forces; and the area included between the two curves represents the work lost in accomplishing this conformation.

These hysteresis curves are always obtained even though the anode is in the form of a cylinder or flattened cylinder without the vertical edges; but the *reactive* cusp points in the curves are never obtained save with two plane anodes connected together.

Zeleny* has found a similar very curious hysteresis effect in the currents obtained from the ions from a platinum wire when heated and exposed to ultra-violet light. When the metal was cooling these currents were greater than those for the same temperature when the metal was being heated. In this case heating the wire produces some change in its surface, possibly in the amount of gas condensed thereon or absorbed by it, from which it recovers very slowly.

As B voltage is increasing and A current is increased and decreased, I find that the points at which the cusps occur on the increase and decrease A-B curves coincide more and more nearly, and at the same time these cusps become less and less violent. The hysteresis effect is less pronounced as the B voltage is increased. As shown in the curves for a large B flux the two A-B curves for increasing and decreasing A current coincide almost exactly until B flux is reduced to a certain amount. They may again cross each other at a lower point of B flux, again diverge, and then coincide once more near their origin. These curves were all taken with audions of the double-wing type, which feature may account for some of the very peculiar characteristics observed.

The filament is always at some part nearer to one wing than the other. Hence the B flux is chiefly concentrated on this wing or portion of wing, like a beam of cathode rays. We may suppose that as the B voltage is increased, as when more heating current is passed through the filament, the flux is increased and spreads out over this wing until a new sheaf or "ray" of ions, starting off from the filament from another part or in a new direction, suddenly leaves that wing and takes by preference a shorter path to the opposite wing. We would suppose that a new path thus taken would first be located on one of the vertical edges of the wings parallel to the filament.

This sudden diminishing of the intensity or density of the original beam of ions may be accompanied by a decrease in the velocity of propagation of the ions, and thus the resultant flux be actually less than before. The reverse operation will occur when the B flux is being decreased from a high value.

When the anode consists of one wing only, no such reverse cusp-points, or reversals of the flux increment, have been obtained. With a single-plane anode, however, there is found a point at which the flux if increasing assumes a sudden increase in magnitude, representing an abrupt rise in the otherwise smooth flux-voltage curve; and the reverse when the current flux is being decreased.

These effects seem to relate to the increased values of the positive variation layers along the vertical edges of the anode which parallel the filament. The distribution of the charge upon the surface of the plate may be described as analogous to that of a thin film of liquid which coalesces and is heaped up along the edges, and from which, when the liquid is by any means drawn away, there is a sudden recession; the liquid, on account of the surface tension, letting go or taking hold of the edge all at once.

It is significant that just at a cusp point the sensitiveness of the audion to the hertzian oscillations attains a marked maximum. Under the critical conditions then obtaining the slightest change in the applied electromotive force is accompanied by relatively great changes in the B flux.

In framing any theory of the action of electric oscillations in the audion a variety of complex, contradictory phenomena are met with, exceedingly puzzling to explain. An example is the fact that a continuous-current instrument either in the A or the B circuit shows absolutely no change of deflection either of increase or decrease, when B is large and the audion in its most sensitive condition. If only the positive halves of the oscillations pass from anode to filament these should increase the reading of a milliammeter in the B circuit during the passage of a long series of wave-trains of sufficient intensity. Or else the negative halves of these oscillations might be expected to diminish to a greater degree the positive charge on the anode, and result in a diminution of the B circuit. Or if both of these acted equally and oppositely no signal would be obtained at all, for the telephone diaphragm is utterly incapable of following such rapid increase and decrease in the B current, even if its impedance would allow these pulsations to pass through the circuit. Neither would the ear detect such vibrations.

If on the other hand the integrated effect of a complete hertzian wave-train were either to increase or decrease the B flux, a long succession of such effects, all of which must be of the same sign, ought to cause a change in the needle's deflection, as when a long Morse dash is sent out from the transmitting station. We have no reason to suppose that one wave-train, the result of one spark, would produce a momentary decrease in the B flux, indicated by a click in the telephone, and that the next succeeding wave-train from the next spark would cause an opposite *increase* in the B flux, and another similar click in the telephone. Such action would of course explain why a loud sound in the telephone might not be accompanied by any change in the sluggish ammeter reading, similar to the case with the magnetic detector.

The following explanation of the phenomena which seems to account for many of the peculiarities of this paradox has been suggested. It should be remembered that if the negative half of the electric oscillation can not pass through the gas from cold anode to the filament the audion electrodes during that half-period will act merely as the two armatures of a condenser. Even when close together, their mutual capacity, when the gas is cold, is exceedingly small, and only a very small positive charge can be held bound on the filament; or if there are sufficient free positive ions in the hot gap the complementary posi-

* For its name, Audion, a title as beautiful as it is appropriate, I am indebted to my assistant, Mr. C. D. Babcock, who has been of utmost service to me in the development of this device almost from its inception.

* Zeleny, Physical Review, vol. xii., 1901.

tive charge will be held just on the outside of the "variation layer" at the anode.

The fall of potential across the variation layers at anode and cathode are proportional to the squares of the velocities of the positive and negative ions; and the ionic velocities are proportional to the electric forces acting upon them. Supposing then that during the positive half of the electric oscillations the velocity of the positive ions is increased at the anode layer, and during the other half period the velocity of the negative ions is increased, due to the changes in the electric force acting upon them. Then regardless of the sign of the change of the velocities the potential drop across the variation layers (which varies with the square of these changes) will be increased during the entire passage of the oscillation train.

The layer will act during this interval like a condenser, the potential drop across which is momentarily increased, which momentary increase will disappear with the passage of the wave-train. It will be as though the plates of a charged air condenser were suddenly further separated and then brought suddenly back to their normal positions; or as though the specific inductive capacity of the dielectric were decreased and then increased. This operation being repeated for every spark at the transmitter a listener in the telephone in the *B* circuit will hear a sound whose pitch is exactly that of the spark, while an ammeter in that circuit will show no variation in its deflection.

As the fall of potential across the variation layers is proportional to the square of the current passing and to that of the impelling electric force, it is readily understood how, by regulating the heating current and the *B* voltage, an optimum value of the electrode drop may be obtained for which the effect from any given received impulses will be a maximum. Also how by varying the distance between the electrodes the sensitiveness of response may be regulated.

Thomson states that the current between two plates for a given difference of potential varies inversely as the cube of the distance between the plates, up to the saturation-current stage. But in the case of the audion, where the cathode is an incandescent filament, the law seems to be quite different. Thus for two anodes of equal area, one approximately four times as far from the filament as the other, the two currents were as 21 to 8. The flux here varies more nearly as the inverse distance.

The potential difference required to produce saturation is proportional to the square of the distance between plates and to the square root of the intensity of ionization. This latter depends on the temperature of the filament.

In the case of the parallel plates, only one of which is incandescent, or if both are heated but below yellow heat so that only ions of one sign (positive) are present and carrying the current, then this current as Thomson shows is:

$$i = \frac{9 R V^2}{32 \pi d^3}$$

where R is the velocity of the ion under unit electric force, V the potential difference, D the distance between the two plates. According to this formula the current varies inversely as the cube of this distance. But this formula will hold only when R is independent of X, which it will not be when the temperature through the space is not uniform. It holds also only for currents that are small compared with their saturation values, for the saturation currents depend not upon the velocity of the ions but upon the number of ions produced in unit time at the surface of the hot electrode.

But in the case of the audion with small potentials, the closer the electrodes are together the more rapidly will the *B* current increase as the potential drop is increased. The trajectories of the ion are shorter and they therefore undergo fewer collisions, reunions, and retardations when the electrodes are close together.

In an audion where the anode is far from the filament the saturation current is not attained with the *B* voltages used with the audion in wireless telegraphy. We sometimes have instead its inverse counterpart, a saturation voltage, so to speak. As shown in the curve, at potentials from 10 to 18 volts a slight potential increment is accompanied by a very large increase in flux. And within these limits the sensitiveness of electric oscillations may be a maximum. The cusp points when present are generally found near these points of inflection in the flux-voltage curves.

In some cases a remarkable lag or "creeping effect" is observed at this saturation stage. As shown in the curve, the milliammeter needle crept slowly up after *B* was raised to 14 cells, from 18 to 26 divisions. The current flux required something like 15 seconds in this instance to attain its full value. The filament in this case may have been undergoing some change which caused it slowly to discharge more and more corpuscles until that stage was reached where the recombination of oppositely charged ions in the gas exactly equaled the output of negatively charged ones from the incandescent surface. Sometimes this creeping is accompanied by a loud frying sound in the telephone.

MAGNETIC EFFECTS.

Thomson shows that at low gas pressures and high ionic velocities the ions, when placed in a strong magnetic field, will travel along the lines of strong mag-

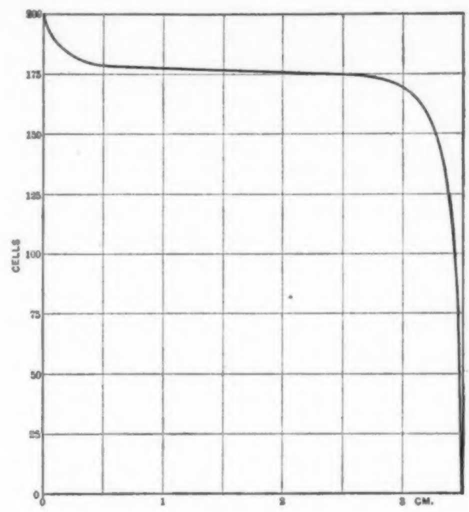


FIG. 7.

netic force; but when the product of velocity and field is small the ion moves parallel to the electric force. If both magnetic and electric forces are uniform, the ions both positive and negative will move in the same direction and perpendicular to both E and H. When the electric field is not uniform but radiates from a point, and the magnetic field is uniform, the ion will describe a spiral traced on a cone of revolution whose axis is parallel to the magnetic field.

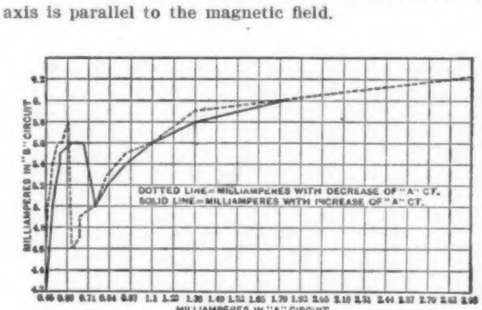


FIG. 8.

If the directions of E and H coincide, the path of the ion itself is a helix of gradually increasing pitch, with its axis parallel to the lines of magnetic force. The radii of the spirals will be small compared to the length of the mean free path of the ions. This is especially true for the negative ions, even when the motion of the positive ions is but little affected by the magnetic field.

If the electric field is not uniform (and it is not in

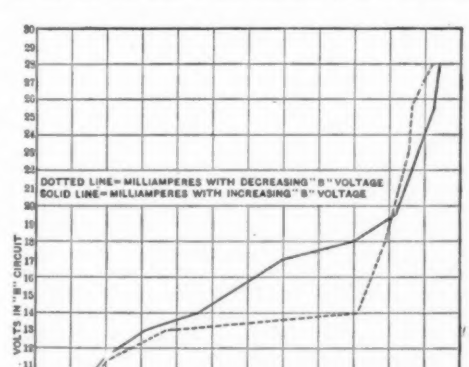


FIG. 9.

the audion where the negative charge is located on the small cylinder of the filament instead of on a plane surface) the paths of the ions will not be cycloids, but in any case the ions will be turned back by the magnetic field after traveling a certain distance d, from their source. Thus they will never get farther than d from their source.

When the lines of magnetic force are perpendicular to the discharge in the cathode-ray tube, the magnetic field at all pressures retards the discharge and diminishes to a considerable degree the great drop in the electric force which occurs in the negative glow.

In general it can be assumed that in a strong magnetic field the ions tend to follow the lines of magnetic force. The smaller the velocity of projection the more nearly does the path of the ion coincide with a line of magnetic force. In cathode-ray tubes the boundary of the negative flow may coincide with the lines of magnetic force.

In the case of the audion if the lines of a strong magnetic field pass through the gas parallel to the plane of the anodes, a marked reduction in the flux is obtained, sometimes amounting to 20 per cent. This effect is greater when the south pole of the magnet is nearest that leg of the filament which is attached to the negative terminal of battery *A*. The negative charge on this leg is of course greater than on the other, for the negative charge on the other is the resultant of the negative potential of battery *B* and the positive potential of battery *A*. And when the lines of magnetic force are so directed as to tend to sweep some of the negative ions off from the parts of the anode nearest to the filament leg which carries the greater negative potential, the reduction of the flux across the gas will be the greatest possible. Hence the magnetic polarity observed.

If the filament extend above the top of the anode, say for 0.5 centimeter, then a magnetic field parallel to the filament legs may tend to force certain lost ions into a downward trajectory so that they will strike upon the anode instead of passing off above it. In this case only is an increase in the *B* flux observed as a magnet is brought up to the audion.

In general the flux will be diminished by the magnetic field. When the magnetic lines pass perpendicular to the plane of the wings the negative ions which are traveling in the direction of the magnetic force, from filament to wing, will be accelerated, but those originally traveling out from the filament in the opposite direction will be bent around or deflected from their direct paths; so the resultant will be a decrease of the total current flux.

When the field is intense, a marked frying or hissing sound in the telephone is heard, especially with the two-wing anode, and when the magnetic force is parallel to their plane and thus affecting mostly the ions which are streaming toward their vertical edges. In the hissing arc parts of the arc are in rapid motion in the unstable portion around the edges of the positive terminal. Possibly also the presence of oxygen in the gas enters into the phenomena here as it does in those of the hissing arc. As the magnetic field lengthens the arc so here it lengthens the paths of the ionic discharge.

The hissing is much more violent when the surfaces of the anode instead of being plane are punched full of little holes whose ragged and protruding edges offer a greatly increased opportunity for the ions to travel irregularly under the combined forces of the magnetism and of the electric charges heaped up at all such points and edges. In this particular audion, I could get a great range of singing or squeaking sounds as the heating current was varied. Where the velocity of the ions is a maximum their deflection by the magnetic field will be lessened.

If the *B* flux is too great to give maximum sensitiveness of response, bringing up a magnet to the audion will increase the strength of the wireless signals, because of the reduction of the *B* flux. Or if this flux be already below the optimum then the presence of the magnet may decrease the sensitiveness. This effect may be more pronounced for one wave-frequency than another, in which case the audion can be attuned by regulating the magnetic field to which it is subjected.

Consider the case where the electric oscillations instead of being introduced into the audion through its interior anode are brought up to a metal plate outside a vessel. Electric displacement currents instead of conduction currents must then act upon the ions within the vessel and on the charges upon the electrodes.

Now in the case of an electromagnetic wave, where H and E are perpendicular to each other and to the direction of propagation, Thomson shows that if the product of $H \times e$ is large (e being the electric charge on a carrier) the average velocity of the ion parallel to the direction of E is zero, and the wave will carry the ion along with it. When, however, $H \times e$ is small (no external magnetic field) the effect of the Hertzian wave will be to superimpose on the undisturbed motion of the ion a small vibratory motion parallel to the electric force of the wave and thus perpendicular to its direction of propagation.

A very convenient form of audion for investigating the relations which the distance, area, etc., of the electrodes bear to its response is had by using a pool of mercury for the anode. This is conveniently held in one or more pockets blown in the walls of the glass

vessel, and the filament so placed as to pass closer to some than to others.

Quite frequently I obtain with this arrangement two maxima of sensitiveness to the same transmitter, the filament heating current remaining unchanged; thus one maximum for $B = 12$ volts and a second for $B = 18$ volts. Again the sensitiveness is maximum when the mercury surface is as near as possible to the filament. When a globule has rolled out of its pocket, exposing a new surface for the anode, sometimes half a second elapsed before the sensitiveness is again restored. This form of mercury tube was especially sensitive to the influence of a magnetic field.

The optimum or critical voltage of B becomes less after this audion has been heated a little time, as though the heated mercury vapor began to act to increase the conductivity of the gas. This critical voltage keeps reducing as the vaporization proceeds, and with a sudden jar on the tube I can bring this down, one cell of B at a time, accompanied by a loud click in the telephone at each reduction. Sometimes a similar reduction of the B flux amounting to as much as 25 per cent can be obtained with the double platinum wing type of audion, by striking it smartly; or a sudden increase in the flux may be obtained.

The heating current when a large anode surface is used is less than that required to produce the same degree of sensitiveness with a small pool of mercury as anode. In general the flux is quite proportional to the area of the anode, other conditions remaining unchanged. A mercury arc also may be substituted for the filament, but such an arrangement is apt to be noisy in the telephone.

When the hertzian oscillations are passed through the filament instead of through the gas, they require to be of great intensity to give any response whatever. Any results from the added heating effect which they may contribute to the filament are quite insignificant. The response when the audions are connected up in parallel, or series, is always less than for one alone.

In a tube whose two-plane anodes are fitted on hinges and backed with small iron disks so that their distances from the filament can be regulated by an external magnet, I find the response to a long wave-length greatest when this distance is the greatest possible; while to a wave-length of about one-half this, the response is decidedly better when the wings are nearer to the filament. Of course the B flux is greater in this latter case, other conditions being unchanged; but the selective quality in this tube just described seems to be due to the regulations of the distance between anode and cathode rather than to other factors.

The manner in which the audion should be located in the oscillating circuit, as well as many other considerations, show conclusively that it is a "potential-operated" rather than a "current-operated" relay receiver. At the same time its advantageous sluggishness of action, as explained above, renders it additive in its response to the energy of an entire wave-train or even of a series of wave-trains. Hence its excellent and marked selective qualities.

A large number of experiments have been carried out with a view to reducing the filament heat necessary to give the inclosed type of the audion the extreme sensitiveness which now characterizes it. This is now attained at normal brilliancy of the filament, or a little below; never at excessive heats. Thus the life of an audion should be that of an incandescent lamp of the same class of filament and voltage.

Filaments have been coated with alkali metals or salts, or vapors of these introduced into the tubes. Experiments along these lines and with various dissociable gases are being pushed with gratifying promise of our soon being able to achieve the present marked sensitiveness even at red heats; or of still further multiplying the sensitiveness.

Radio-active compounds, applied for example between juxtaposed metal disks and heated, give little encouragement. At the low voltages used no increase of conductivity by their means has been observed, although Swinton has found that a radium coated cathode in a cathode-ray tube has a marked action in facilitating a luminous cathodic discharge, when the cathode is heated to redness. The mere presence of radium in the tube is insufficient to produce the effect.

Spontaneous ionization, that is the ionization independent of the electric field, as for example that produced by the X-rays, does not increase the current flux. Only the ions produced by the electric field itself close to the cathode, and by the heat of the cathode, are effective.

It is required that the audion be made with scrupulous care; a trace of impurity in the gas may produce surprisingly large effects in the potential drop across the variation layer. The presence of a mere trace of moisture may cause great difference in the behavior of a tube.

In all this work a bewildering host of new and puzzling phenomena is continually encountered. By its nature clean and pretty, fascinating in its ever new phases, gratifying in the efficiency with which it responds to the difficult demands of a new and intricate art, the audion combines infinitely delicate matter and forces, at once offering rich fields for study to the physicist and delight to the practical man.

ELEMENTS OF ELECTRICAL ENGINEERING.—VI.

INCANDESCENT LAMPS.

BY A. E. WATSON, E.E., PH.D., ASSISTANT PROFESSOR OF PHYSICS IN BROWN UNIVERSITY.

Continued from Supplement No. 1664, page 326.

When resistance is offered to the passage of a current of electricity, heat is produced. The case is analogous to that of mechanical friction, which is always a source of heat. In the transmission of energy, the evolution of heat, being a direct waste, is to be minimized, therefore suitably large conductors of good material are selected; then at the place where heat is wanted, the device which utilizes it is made of high resistance material of small mass. In the electrical case copper and carbon represent, in a remarkable degree, these two extremes, the metal having about 3,000 times the conductivity of the other. Since the amount of heat produced in a conductor varies directly as the resistance, a given current will heat a rod of carbon 3,000 times as much as one of copper. This proportion is so large that the copper rod may be considerably extenuated and allow the carbon to be some miles distant from the source of current, and yet allow the heat energy to be transmitted with only a few per cent loss.

Early forms of incandescent lamps were made with platinum wire loops in globes to which free access of air was permitted. Oxidizing, therefore, was inevitable, with consequent short life of the wire; but further, platinum is not a sufficiently refractory metal, and the point of incandescence is too near that of fusion; therefore, a slight excess of current readily melts the wire. By Joule's law, the degree of heating is known to vary as the square of the current, so a small increase in strength of current quickly reaches the danger point. Further, platinum has a resistance only about sixteen times that of copper—altogether too low a proportion to admit practical distribution of current to a large number of lamps at a distance from the dynamo.

The problem of the "subdivision of the electric light," as it was called, was really solved by Edison, in 1879. Already famous for his invention of the quadruplex telegraph system, and of the carbon-button telephone transmitter, the immediate effect of his new invention of the proper construction of an incandescent electric light was rather over-estimated; for immediately upon the announcement of the news in London, gas stocks took a violent decline.

The invention was really two-fold, for it consisted in making durable lamps of high resistance, and of connecting them in parallel, or multiple, with each other, rather than in series; this second part was really made possible by the attainment of the first. The multiple method of connecting limits the potential the dynamo is called upon to generate to that required for one lamp. Increase of number of lamps merely means more current; and, because each individual path is of high resistance, the total number of amperes does not exceed reasonable engineering abilities. By this method, now technically known as the "constant-potential" system of distribution, each lamp, or other connected device, is rendered as independent of every other as are separate gas taps or water faucets.

Edison sought the ends of the earth to find the

Fig. 24.—Details of Lamp Construction.

proper material for making the carbon threads or "filaments," as they are now called. He finally adopted shreds of bamboo. Other experimenters tried various other materials, bank-note paper, cotton, and silk threads receiving particular attention. Particularly has the extreme uniformity of the last made its use extremely enticing. Still the results with the bamboo were so good that its use was very general for more than a decade. But whatever the material of the filament, its incandescence in the open air would mean its almost instantaneous burning and disappearance. Edison inclosed the carbon in glass globes from which the air and other gases were highly exhausted, and led the current through wires sealed in the glass. He was not the first to use carbon filaments, but was the one who first made them of high resistance and adopted practical methods of manufacture. His fundamental patent, that was fiercely contested and openly infringed for years, involved the clear statements of the "combination of a high resistance carbon filament contained in a vacuous globe, and connected by wires sealed in the glass." The conflicting claims of other inventors were so interminable that the final decision of the courts in Edison's favor was not given until the patent had nearly expired. Others did make valuable inventions of processes, notably that by Sawyer and Man, and known as "flashing," to which the Edison Company did not have the right; but it was a valuable asset of some of the competing companies.

The successive steps in the construction of incandescent lamps form a series replete with highly ingenious schemes and refined processes, attended with a delicacy of manipulation that is not exceeded in the making of a watch. Fifty distinct operations and forty inspections are needed to make a reliable lamp that, however, may sell for twenty cents. Though simple, even to plainness, it represents in some respects a device as near to absolute perfection as human hands and minds can produce.

Previous to about 1890, the use of the bamboo for filaments was very general, and though displaced since that time by the more uniform cellulose, the original process is sufficiently interesting to deserve mention. Selected sticks of the wood were cut in about six-inch lengths and split into as fine straws as ordinary knives would permit. They were then reduced to desired sizes by being drawn through successively smaller holes in hardened steel plates. Experience alone was the guide in determining just what lengths and diameters were needed to produce filaments of a desired resistance. Edison had arbitrarily decided that not less than 100 volts was needed for good dynamo operation, and with ten more volts thrown in, to be on the safe side, the present standard of 110 volts was established. The filaments were next bent over an iron block and packed in powdered charcoal in an iron or clay crucible and submitted to the intense heat of a furnace for ten to twelve hours. The volatile and easily combustible portions of the woody substance thereby disappeared, leaving, as it were, only the skeletons of the former structure—carbon threads. They were black and fragile, shrunk to about two-thirds of their former size. The fact that they were not completely destroyed is attested by the experiment of burning a newspaper in an open fire. If the draft is not too strong, the flame will leave behind a carbonaceous film of the merest gossamer thickness, yet on those delicate ashes can be seen the still denser carbon of the printer's ink.

With Edison, the next step was to attach the filaments to wires and seal them in globes, but the licensees under the Sawyer-Man patent submitted them to the "flashing" process. By this now universal process the individual threads are temporarily held in electrical contacts in an attenuated vapor of gasoline. Momentary passages of the current, whereby light is emitted in flashes, are allowed; the heat is sufficient to decompose the gas in the neighborhood of the filaments and solid carbon is deposited; naturally those parts that are the smallest will heat the most, deposit the most carbon, and thereby bring the whole filament to uniform size. This deposited carbon is denser than the original; in fact, it is pure graphite, and offers a smooth surface with metallic luster, so much so as readily to give the impression that the filaments are

actually metal wires. Considerable mechanical strength is added to the slender filaments by this extra coating. By well known laws of physics, a shiny surface is a poorer radiator of heat than a rough blackened one, and only about one-sixth as much energy is required to heat a given section of the graphite substance as of the carbonized wood. Lamp manufacturers strive therefore to make the "base" or central carbon as small as possible in comparison with the deposited carbon.

The next step is to prepare a "mount" or "stem" for the filament, consisting of a suitable piece of glass, through which are sealed two bits of platinum wires. Platinum is the only metal that has the peculiar property of being wetted by molten glass. The intimate contact resulting from the glass sticking to the platinum precludes the possibility of an initial leak, and the further fact that the two substances have the same rate of expansion, or contraction, for changes in temperature makes the seal of permanent reliability. In commercial forms platinum costs about as much as gold, hence the smallest permissible amount of the metal is used. Indeed these tiny wires that are hardly visible in their glass seal look too small to convey the current; but the explanation is that the current itself is small, being only about half an ampere in the case of a 110-volt lamp. Edison's method was to make the stems in pairs, the successive steps being depicted in Fig. 24, parts 5 to 11. Whatever the method, the result is a flattened bunch of glass, through which the two platinum wires, about one-quarter of an inch long, passed and continued by having copper wires a

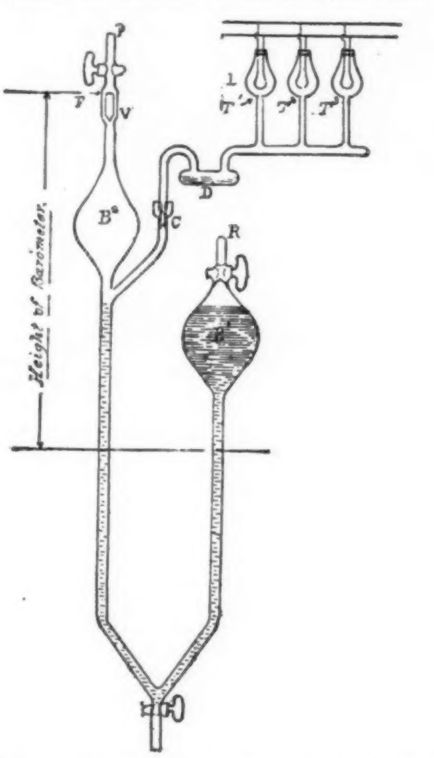


Fig. 25.—Geissler Mercury Air Pump for Exhausting Lamps.

couple of inches long soldered to them. The neck of the tube through which the latter wires pass loosely is about three-eighths of an inch in diameter and one inch long, flaring at the outer end to about twice that diameter, with possibly a temporary extension for convenience in handling. The center of the globular portions in 10 and 11, Fig. 24, is the location of these flanges. If the filament is to be "anchored," one end of a fine nickel wire is imbedded in the glass between the two of platinum; but as it does not pass entirely through, there is no danger of a leak from this source.

Various and curious means, even to the point of being cumbersome, were employed by the early experimenters to attach the carbon filaments to the metallic wires. The present method is to stick the two parts together with a carbon paste or "dough," of somewhat secret composition, and then to solidify and reinforce this joint by electroplating upon it a deposit of carbon from a hydrocarbon fluid. Local heating at the desired point is permitted by adjusting the amount of immersion. This operation is attended with some danger from fire, and some discomfort to the employees by reason of the peculiar odor arising from the solution. In case the anchorage is to be used, the filament is laid in the hooked end of the nickel wire and attached with a little of the paste.

Thus fitted and thoroughly dried, the filament is ready to be inclosed in its glass globe or bulb. Ordinarily, the lamp manufacturers do not blow their own bulbs but purchase them in a half-prepared condition. As received from the glass works, the large end is smooth and the small end has a shank about three inches long and three-fourths of an inch in diameter. Not a little ingenuity has been displayed in replacing manual operations by machinery in making the millions of bulbs demanded annually by the devotees of electric lights. A little tube of glass, about two inches long and three-sixteenths of an inch in diameter, is pressed into the semi-circular end of the bulb—thenceforth to be used as a handle and for a means of attaching to the air pump—and the larger tube cut off at the point where the pear-shaped portion begins.

A help in understanding the manipulation of the glassware will be obtained from reference to Fig. 24. At 1 is seen the plain bulb as received from the glass works. A tiny flame is directed against the center, and a little tip blown out, as seen at 2, and to this the tube 3 is joined, making the structure appear as in 4. The right-hand end is then cut off, as mentioned.

Though made of carbon, the filament is sufficiently flexible to admit such bending as will enable it to be thrust through the hole in the bulb, and the flaring edge of the stem is then fused in place so as to make all appearance of a joint vanish; the lamp then appears as at 12 in Fig. 24. It was formerly customary to join six to ten lamps by their small tubes to a common fork for attachment to the air pump. The exhaustion was accomplished by means of mercury pumps, first those of the Sprengel type being employed, then Geissler's form as modified by Weston. The former can produce a more nearly perfect vacuum, but are slower in their operation than the other, and, further, have the objectionable feature of allowing the fumes of mercury to escape into the air and endanger the health of employees. Geissler pumps are entirely inclosed. A view of one arranged for exhausting a row of lamps is given in Fig. 25. Fifty or more of identical construction were arranged in a row and worked simultaneously as manipulated through the medium of a three-way valve. The two bulbs B^1 and B^2, of about one quart capacity each, are connected by a U tube, with a cock at the bottom for drawing out the mercury for occasional cleaning; openings for connecting to the iron piping of the suction system are shown at *P* and *R*; ground glass check valves are at *V* and *C*; a bulb or tube containing phosphoric anhydride for absorption of moisture is shown at *D*; three lamps wired to a neighboring circuit are joined to the rest of the structure at *T*. When idle, the mercury stands at the level shown. If *R* is closed and the mechanical pump is connected with B^2, air is exhausted directly from B^2 and the lamps; a few moments suffices to exhaust about twenty-nine thirtieths of the air, and the function of the mercury is to assist in the removal of remaining thirtieth. *R* is then opened, thereby allowing atmospheric pressure to drive the mercury from B^1 to B^2; the rise of mercury in B^2 will close the valve *C* and open *V*, and expel whatever air was in the vessel, past all hope of re-entering. Nearly thirty inches difference of level of the two mercury columns will exist. Exhaustion is then made from *R*, allowing the mercury to resume its former level, as shown in the cut. As soon as the valve *V* ceases to float, it drops into its socket, and then *C* opens. Whatever air remained in the lamp bulbs then expands so as to share its volume with the emptied B^2. This operation is repeated every two or three minutes for several hours, if need be, until the exhaustion is practically perfect. Possibly one one-millionth of the original amount of air still remains. The final portion of the pumping is done with the filaments heated, first to dull red, then to full incandescence, thereby driving out any air or other gases that may be occulted in their pores. A small gas flame is then directed against the small tubes close to the lamp bulbs, softening the glass and allowing atmospheric pressure to close the walls, seal the tips, and allow complete removal of the lamps. The appearance is then as seen at 13 in Fig. 24.

The departures of more recent methods of manufacture from those just given are principally in the substitution of cellulose for the material of the filament, and the "chemical" vacuum for that of the mercury pump. As for the first, cotton is dissolved in a hot solution of zinc chloride, forming a dark viscous liquid, expressively denoted as "squirt-mixture." This is "squirted" through fine nozzles directly into a vessel containing alcohol. It at once hardens and assumes a silky appearance—indeed a commercial name for this product is "artificial silk." Produced in cheaper ways it is destined to have an important bearing upon the natural silk industry. These cellulose threads can be readily handled and coiled; they can be looped and carbonized as were those of bamboo, with the gain that whereas the woody filaments, when examined under a microscope, appear like charred cord-wood, those of the cotton cellulose still appear as uniform as polished rods. The extreme fineness and uniformity with which the carbon threads can be produced has made possible lamps for circuits of as high potential as 250 volts. The second modern step has been the improvement of the mechanical pump, whereby with two cylinders in series with each other, their pistons packed with a heavy oil that has no vapor tension, almost a perfect vacuum can be produced. Individual instead of clusters of lamps are exhausted. The method of ridding the globes of the final traces of oxygen is

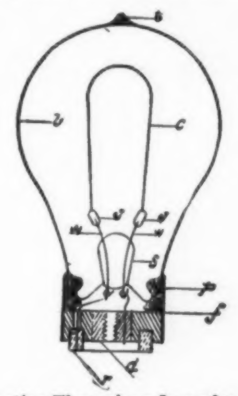


Fig. 27.—Section Through an Incandescent Lamp.

the invention of an Italian; the patent was purchased by the General Electric Company, which licenses other manufacturers upon payment of a royalty of one cent per lamp. Before attaching to the pump, a speck of red powder, probably amorphous phosphorus, is introduced into the bulb. A few minutes' operation of the pump suffices to remove almost all the air. The current is then turned on, heating the filament; a bluish light is emitted, and the bulb is hot—evidence of a poor vacuum; the heat, however, quickly ignites the phosphorus, and it burns at the expense of the remaining oxygen; a diminutive cloud of ashes can also be seen to fall; the filament at once springs into sparkling incandescence. The vacuum is conceived to be perfect.

After removal from the pumps the brass and insulation structure designated as the "base" is attached to the glass bulbs by means of plaster of Paris, and the copper wires soldered in place. Three patterns have been largely used as shown in Fig. 26. Of these the Edison style was the first made and is still the best; the Westinghouse is as cheap, but does not guarantee so reliable a contact with the corresponding parts of the socket; the Thomson-Houston has the qualification of having the outer shell out of contact with the circuit, but is a little more expensive to make, and is apt to loosen from the socket; its use is being rendered obsolete by the practice of lamp manufacturers in charging one cent more for this style than for either of the others. The Westinghouse, too, is somewhat in disfavor, so within a few years it is likely that the Edison alone will be in common use.

A section showing a lamp with nearly circular bulb, as used for series street lighting, is shown in Fig. 27. It happens to have a T-H base. The different parts can be picked out, as the bulb *B*; the two platinum wires *W* in the glass stem *S*; the carbon filament *C*; the centrally threaded plug *D* and the ring *R* of the base. It will be observed that the lower end of the bulb is molded with a groove for the more reliable holding of the plaster.

A final step in the manufacture is the photometer test, and the labeling. Lamps that are to be of a given candle power are made to give that amount of light in comparison with an accepted standard, and the voltage necessary to bring it about is marked on a label and pasted to the globe. All of those within a certain range of this experimental rating are then relabeled as just alike—those outside the restricted

Fig. 26.—Edison, Thomson-Houston and Westinghouse Standard Bases.

limits being collected in other groups. Although surprisingly close results can be predetermined, some variations are bound to result; but no lamps are wasted, as central stations normally need quite a variety of slightly varying lamps to fit the needs of different parts of their circuits.

As for the "efficiency" of an incandescent lamp, 3 watts per candle power is about the limit for economy for use on circuits that have the closest regulation of voltage. Ordinary circuits require 3½-watt lamps, and badly regulated ones would need 4-watt lamps. That is, the breakage of the higher economy lamps due to momentary excess voltages would more than offset the extra cost of fuel. Standard 16-candle-power lamps would then take respectively 48, 56, and 64 watts, meaning that 15, 13, or 11 such could be operated per electrical horse-power. A maximum of 240 candles per horse-power is the attainment as compared with three or more times that amount from an arc lamp.

Within the past few months there has appeared an unexpected competitor of the carbon filament lamp, in a curious resorting to metallic filaments. Tantalum has a higher melting point than platinum, and highly satisfactory results seem to be assured from its use. Lamps are now advertised, costing about twice as much as the ordinary ones, that give 22 candle-power with an expenditure of about 44 watts, or only 2 watts per candle-power. The life of the lamp is guaranteed to be 700 hours—about equal to the economical life of a carbon lamp. The long length of wire required to get the requisite resistance, makes the suspensions appear rather cumbersome; but lamps are not made for the purpose of being gazed at, and criticisms of such character are not particularly valid. It would indeed be strange if the carbon filament lamp, after having so exclusively occupied the field of incandescent lighting for a quarter of a century, should find itself thus rudely displaced.

Another type of lamp with which many engineers and even scientists have struggled for years is the Nernst. The luminous body is of about the same materials as the mantles of Welsbach gas burners—thorium and cerium—but the lamp is expensive and rather delicate in operation, and sufficient space cannot here be taken to describe it. Along with mercury vapor lamps and the like, it may form the subject of a later chapter.

The next will be on the "Principles of Direct-Current Motors."

(To be continued.)

PANAMA CANAL PROGRESS.

THE ORGANIZATION AND DIVISION OF WORK.

THE great progress made in the building of the Isthmian Canal during the past year is described in the latest report of the Canal Commission, a body which has been in charge of the work since April 1, 1907, and which is the product of several important changes, both in personnel and in organization. The personnel has been altered owing to the resignation of Mr. Theodore P. Shonts and others, while the organization has been changed by the combination of the offices of chairman and chief engineer, and the passing of the requirement that the members of the Commission should live on the Isthmus.

The actual work of construction and of maintaining the working force in an effective condition is in the hands of three departments, the Department of Construction and Engineering, the Department of Labor and Quarters, and the Department of Sanitation.

In order to utilize the services of the engineer members of the Commission in construction work and to secure a closer supervision of the details of the work through a head directly responsible to the chairman and Chief Engineer, the Department of Construction and Engineering was subdivided into departments, each in charge of a member of the Commission, as follows: Department of Excavation and Dredging, Department of Lock and Dam Construction, Department of Municipal Engineering, Motive Power and Machinery, and Building Construction.

The Department of Excavation and Dredging embraces the Culebra division, extending from the Chagres River to Pedro Miguel; the Chagres division, extending between deep water in Lake Gatun and the Chagres River; the Colon dredging division, extending from Gatun to deep water in the Atlantic; and the La Boca dredging division, taking in all excavation between the La Boca locks and deep water of the Pacific.

The last annual report of the Commission, dated December 6, 1906, states that during the year the first stage of canal work, that of preparation, has virtually been passed and the Commission finds itself in position to enter upon the second stage, that of actual construction of a lock canal at an elevation of 85 feet, authorized by Congress in June last.

This statement is peculiarly applicable to the Culebra division, on which efforts have always been concentrated, for, irrespective of the type of canal to be constructed, the excavation in this section of the territory had to be done. Moreover, for the time being it was the most important part of the work. That the preparation was efficiently done and the organization effective is best attested by the results accomplished and the relatively small falling off of the output during the wet months; thus the amount of material removed from the Culebra cut was 4,047,071 cubic yards, place measurement, from January 1 to June 30, out of a total of 5,570,432 cubic yards for the fiscal year.

The Culebra division is practically ten miles in length, and early in the wet season it was recognized that general supervision of all the steam shovels or all the trains of the entire division under one supervisor or superintendent was not productive of the best results in fixing responsibility in case any part of the work was not progressing satisfactorily, consequently a slight change in organization was effected on July 1. This consisted in subdividing the division into five construction districts, each under charge of a superintendent of construction, who is held responsible for the work in his district. Better results have followed with less friction. Since the close of the fiscal year the monthly output improved over the early months of the wet season, as indicated by the table.

It will be seen from the table that the maximum monthly amount of material excavated in the Culebra division during the fiscal year was 879,527 cubic yards, which was removed in April, 1907. This amount exceeds by 75 per cent the maximum monthly excavation, as given in available records, made by the French in the Culebra division, their highest monthly total in the Culebra division being 502,250 cubic yards in February, 1886.

With the exception of a very small proportion of material removed by hand from the quarry in the canal prism at Bas Obispo, all material is handled by steam shovels and dirt trains, and is carried to dumps situated at distances varying from 1 mile to 15 miles, the average haul at present being about 10 miles.

The work of this division is dependent on mining, steam shovels, transportation, and dumps, and the great problem in the construction of this portion of the canal is the disposal of the excavated material. In the main this has been disposed of at various localities favorably situated with regard to the cut. The systematic performance of the work and the necessity for additional material in completing other parts of the work have made it necessary to arrange for such a disposition in the future as will be most beneficial to the work in its entirety.

This disposal work is particularly difficult during the rainy season, for the material on the dumps being loose, it is, when wetted by the heavy rains, incapable of sustaining the weight of a train, so that considerable delay, and in some cases the abandonment of the use of the dumps until drier weather, is caused.

The efficiency of the dams depends upon their having sufficient weight and tightness to impound the water without leakage and without danger to the stability of the structures. The weighty material, or rock, is to be furnished in each instance by material from the Culebra cut and the tightness is to be secured by the selection of suitable material to be obtained from the products of dredging. In other words the construction of the dam is intimately connected with the excavation of the Culebra cut.

On the Chagres division only preparatory work was done during the year, consisting of surveys and borings to determine the character and amount of earth to be removed. The Chagres River crosses the center line of the canal twenty-three times within the limits of the division. The differences of level between the river and portions of the division are such that whatever excavation in the dry is undertaken will be subject to more or less interruption from overflow during the wet season. As the rock portion of the cut can be removed or broken up by blasting more economically in the dry than in the wet, it is desirable that work be undertaken without delay; though the amount to be done is relatively not large, the conditions are such as to militate against rapid progress.

Since the close of the fiscal year work has been commenced and steam shovels diverted from Culebra division until others under contract are delivered.

The Colon dredging division consists of the Mindi and Colon districts. In the former about 700,000 cubic yards of material in the vicinity of Mindi Hills will be removed by steam shovels, this method being more economical since the borings made during the fiscal year indicate that a large percentage of rock is found in this locality; the remainder will be dredged. The necessary clearing and other preparations were made, and excavation by steam shovel was begun, toward the close of the year.

In the Colon district dredging operations were in progress throughout the year, the greater part in the vicinity of the dry dock slip and along the route of the old French canal as far as Gatun. The latter was done to make a navigable waterway for the transportation of the materials that must be taken to the site for the construction of the locks. The dredging fleet con-

Month.	Number of Working Days.	Daily Average Number of Shovels at Work.	Output.
1907.			Cubic Yards.
July	26	43.38	770,570
August	27	39.70	786,866
September	24	38.50	753,468

AMOUNT OF MATERIAL EXCAVATED IN THE CULEBRA DIVISION SINCE THE UNITED STATES ASSUMED CONTROL (PLACE MEASUREMENT).

Fiscal Year Ending June 30.	From Canal Prism.				Total Excavation, Including Canal Prism and Accessory Works.			
	Earth.	Rock.	Not Classified.	Total.	Earth.	Rock.	Not Classified.	Total.
	Cu. Yds.	Cu. Yds.	Cu. Yds.	Cu. Yds.	Cu. Yds.	Cu. Yds.	Cu. Yds.	Cu. Yds.
1904	....	....	60,107	60,107	....	....	60,107	60,107
1905	327,404	230,875	183,365	741,644	327,404	230,875	183,365	741,644
1906	764,327	742,235	.....	1,506,562	764,327	742,235	....	1,506,562
1907	2,288,190	3,282,233	....	5,570,432	2,413,358	3,325,613	29,043	5,768,014
Total	3,379,930	4,255,343	243,472	7,878,745	3,505,089	4,298,723	272,515	8,076,327

AMOUNT OF MATERIAL EXCAVATED MONTHLY IN THE CULEBRA DIVISION DURING THE FISCAL YEAR ENDING JUNE 30, 1907 (PLACE MEASUREMENT).

Month.	From Canal Prism.			Total Excavation, Including Canal Prism and Accessory Works.			
	Earth.	Rock.	Total.	Earth.	Rock.	Not Classified.	Total.
1906.	Cu. Yds.	Cu. Yds.	Cu. Yds.	Cu. Yds.	Cu. Yds.	Cu. Yds.	Cu. Yds.
July	48,272	111,517	159,789	48,272	111,517	....	159,789
August	53,839	190,984	244,823	53,839	190,984	....	244,823
September	106,224	185,228	291,452	106,224	185,228	....	291,452
October	109,903	217,106	327,009	109,903	217,106	....	327,009
November	72,618	149,024	221,642	72,618	149,024	....	221,642
December	109,158	169,488	278,646	109,158	169,488	29,043	307,689
1907.							
January	246,653	293,182	539,835	267,458	299,292	....	566,750
February	293,461	315,038	608,499	316,461	322,651	....	639,112
March	397,651	372,042	769,693	434,970	380,300	....	815,270
April	352,621	488,993	841,614	382,344	497,183	....	879,527
May	284,444	378,400	662,844	298,756	391,609	....	690,365
June	213,355	411,231	624,586	213,355	411,231	....	624,586
Total	2,288,190	3,282,233	5,570,432	2,413,358	3,325,613	29,043	5,768,014

sisted of one old French ladder dredge, one five-yard dipper dredge, and one 16-inch suction dredge; and there were under contract another dipper dredge and a seagoing suction dredge similar to those now operating in New York harbor. For use in connection with this fleet, six steel hopper barges were under contract. During the year the dredges in use were served by a tug and four old French self-propelling dump barges, known as "clapets."

The excavation by dredges during the fiscal year amounted to 1,112,231 cubic yards, place measurement, of which 43,602 cubic yards were rock; 17,000 cubic yards of the total were removed from the canal prism, the remainder of material being from accessory works.

In the La Boca dredging division the surveys in progress during the previous fiscal year to determine the line of the canal were continued and completed. Test borings were made in the channel west of Naos Island to a depth 40 feet below the low water of spring tide to ascertain the character of material to be removed. The dredging fleet for this division consisted of one old French ladder dredge and one five-yard dipper dredge. A second French ladder dredge was undergoing repairs and was put in operation after the close of the fiscal year. A seagoing dredge similar in type to the suction dredge for the Colon end is under contract and when finished will proceed under its own steam by way of Cape Horn to Panama. The ladder dredges and dipper dredges were served by seven French self-propelling dump barges, and a contract was made for three steel hopper barges to be used for the same purpose.

During the past fiscal year 1,235,897 cubic yards of material were dredged from the division, of which 64,352 cubic yards were taken from the canal prism and the remainder from accessory works.

The Department of Locks and Dams embraces the Gatun locks and dam, the locks and dam at Pedro Miguel, the locks and dams at La Boca, meteorology, and river hydraulics.

The locks are in pairs, each, as now proposed, with usable lengths of 1,000 feet and widths of 100 feet. The adopted project contemplates a flight of three locks at Gatun, a flight of two at La Boca, and one lift at Pedro Miguel.

Prior to as well as subsequent to the adoption by Congress of the 85-foot level canal in June, 1906, borings were made to determine the character of the foundations at the various lock sites. The classification of the data so obtained was recorded in such a way as to cause considerable adverse comment, questioning the suitability of the material for the purpose. To actually develop the character of the foundations on which the locks are to rest, five test pits each 6 feet by 8 feet were sunk to the depths of the lock walls at Gatun, two at Pedro Miguel, and one at the spillway in the Gatun dam. The outcropping of trap rock at La Boca, which borings showed extends to proper depths, rendered such examinations of the foundations for these locks unnecessary. On the completion of the test pits a Board of Consulting Engineers, consisting of Alfred Noble, Frederick P. Stearns, and John R. Freeman, made a personal examination of the material, and under date of May 2, 1907, reported as follows:

"We beg to record that we found that all of the locks of the dimensions now proposed will rest upon rock of such a character that should furnish a safe and stable foundation."

Since then careful borings have been continued over the entire area in order to secure a contoured plan of the rock surface with a view to the most economical adjustment of the locks to the site.

Subsequent to the adoption of the project, studies were begun of locks, gates, and sluiceways. From these studies the Commission finally decided upon the method of filling and emptying the locks and the number and type of gates. The gates are in duplicate and of the miter type, except that the rolling gate similar to that now in use on the Ohio River will be substituted for the duplicate set at the lower end of each summit-level lock. In addition there will be provided an auxiliary pair of gates at the lower end of each flight for use as cofferdams in case it may be necessary to pump out the locks, and it has been determined tentatively to adopt a swing-bridge type of dam for emergency use. The designs for the locks and gates are progressing satisfactorily.

Excavation of the site of the Gatun locks and dam by steam shovels was begun in September, and by the end of March four shovels were at work, and a total of 484,362 cubic yards, place measurement, of earth and rock were removed during the year.

About 573 acres of the site to be occupied by the dam were cleared of timber, and a pile trestle was partially driven along the 30-foot contour on the upstream toe of the dam for the purpose of depositing rock from Bas Obispo as an integral part of the dam. Contracts were entered into for two 20-inch pipe line suction dredges for construction use on the lower portion of the dam.

The cross section of the dam has been slightly changed and the upstream slope made more gradual than that originally proposed.

The report of the Board of Consulting Engineers advocating the lock canal project provides for the construction of a spillway through the dam. The work of excavation was commenced in April, and one steam shovel was placed at work; 3,832 cubic yards, place measurement, were removed and dumped in the near vicinity.

A topographical survey was made of the basin of the lake up to the 100-foot contour, and all the saddles in the hills were carefully examined to ascertain the nature of the material composing them. The survey was practically completed at the close of the fiscal year, from which the area of the lake is determined to be 164.23 square miles.

Broken stone needed for concrete construction in the locks cannot be obtained in the immediate vicinity of the site, so a quarry of trap rock suitable for the purpose was located at Porto Bello. Surveys of the property were made, and contracts were entered into for furnishing the necessary rock-crushing plant and barges for transporting the product to Gatun.

Besides the pits already noted and the numerous borings made to determine the character of the foundations for the Pedro Miguel locks and dam, work was confined to excavating the lock site, and 162,094 cubic yards, place measurement, were removed. This excavation was done by the Culebra division in connection with the work at Culebra cut, and is noted as part of that output.

During the fiscal year only preparatory work was in progress at the La Boca locks and dams. It consisted of borings at the lock site and along the lines of the two dams, La Boca-San Juan dam and the Sosa-Corozal dam, and for locating and constructing the necessary spillway. At the Sosa-Corozal dam preparations were made for the construction of trestles on the two toes of the dam from which material from Culebra cut is to be dumped. Between the two dumps thus made suitable material for the dam is to be placed. Arrangements were made for the construction of a diversion channel for drawing off water which interferes with the construction of the dam so begun.

A survey was in progress for determining the area of the property that will be submerged by the lake that the construction of the two dams will create.

Three meteorological stations were in operation at the end of the year—Naos Island, Ancon, and Bas Obispo—and a fourth station was begun at Cristobal.

The division of river hydraulics has for its object the collection of data necessary to predict freshets in time to take precautions for the preservation of property, and also for the determination of the amount of water that can be relied upon for supplying the lakes that will exist upon the completion of the canal.

At Alhajuela, rain-gage and fluviograph observations were made from October 13, 1906, to the end of the fiscal year. Similar observations were made at Gamboa and Bohio during the entire year, but not until April were any gagings of the Trinidad and Gatuncillo rivers started, when arrangements were made for discharge measurements of the several channels at Gatun.

The Division of Municipal Engineering has been active in installing sewers, waterworks systems, sidewalks, and the like in the various towns and cities of the zone and in the construction camps. In the city of Panama alone 13,000 feet of water pipe were laid, consisting mainly of extensions to outlying districts; 2,093 houses were connected, 1,048 meters installed, and 133 hydrants, 7 water cranes, and 35 public taps placed.

In the same city 12,232 feet of sewer pipe were placed, while 46 manholes, 62 catch basins, and two large storm-water sewers were built for special drainage purposes.

Sidewalks were likewise laid, and roads macadamized.

When it is considered that this is but one of some eight or ten points where the work of this department is being carried on, an idea of the efficiency of the department can be formed.

The labor supply has been ample to meet demands at all times. The average daily force carried during the year was 2,593 employees.

Under the supervision of the division of motive power and machinery came the work of the erection and preparation for service of the machinery necessary in canal construction, and its maintenance in good repair; the installation and operation of air-compressor plants; the performance of work in connection with electrical installations, and the manufacture and repair work for other divisions. During the year 2,479 employees were carried on the rolls and expenditures made to the amount of $6,360,496.56.

To date the following machinery has been erected and made ready for service: Sixty-three steam shovels, 284 locomotives, 2,706 dump cars, 18 unloaders, 13 bank spreaders, 33 unloading plows, 3 track shifters, and 7 pile drivers.

This work has been done largely at the old plants at Cristobal, Gorgona, Empire, and Paraiso. Work was commenced on new plants at Empire and Paraiso during the year, in order to provide for increased demands made on this division. In addition, limited facilities for handling equipment and making running repairs are being provided at Pedro Miguel, Rio Grande, and Tabernilla.

Engine houses for taking care of engines during the night and making running repairs were provided at Lirio, Cucuracha, Las Cascadas, and Rio Grande.

Coal chutes for delivering coal to locomotives, and which also have appliances for drying and delivering sand to locomotives, are located at Las Cascadas and Pedro Miguel.

Air compressor plants were located at Rio Grande and Empire, furnishing compressed air to operate rock drills, stone crushers, etc. Nine and one-half miles of 10-inch pipe-line mains, with 6-inch and 4-inch leads running into the canal prism, were laid, extending from Bas Obispo to Pedro Miguel. These plants also supply compressed air for operating coal chutes at Pedro Miguel and Las Cascadas as well as such compressed air as is needed at the Empire and Paraiso shops.

A thorough boiler-inspection has been established, covering all boilers on the Isthmus, including those of the Panama Railroad. The jurisdiction of the mechanical engineer, master car builder, and electrical engineer has been extended to cover the Panama Railroad.

The principal work of the electrical subdivision was the construction of electric-lighting plants at Empire and Gorgona. The plant at Empire has a capacity of approximately 4,000 16-candle-power lights. About 10 miles of pole line were constructed in connection with this plant, which now supplies light to practically all buildings at Culebra, Empire, Rio Grande, Enterprise, Cerro, and Lirio. Extensions to Las Cascadas and Paraiso are now under way.

The Gorgona plant was placed in operation in May and has a capacity of about 2,000 16-candle-power lights. Three miles of pole line were connected with this plant, and light is furnished from it to buildings at Gorgona and Matachin, including the Gorgona shops.

Considerable work of a minor character was done, including automatic fire-alarm telegraph systems, the construction of arc-lamp circuits at different points, and other miscellaneous work.

For the accommodation of gold employees 656 quarters, both bachelor and family, were constructed, and for silver employees 335 buildings were erected, consisting of barracks, bath houses, cook sheds, family quarters, and kitchens. For the sanitary department 33 buildings were constructed for hospital purposes. Larger office buildings were constructed at Empire and Ancon and additional office space afforded at Cristobal and Culebra. A school building was constructed at Culebra, and other buildings for similar purposes started at Gatun, Cristobal, and Empire. Seven mess halls for the accommodation of American employees and 11 for European laborers were completed; a large hotel at Tivoli Hill was also built, together with quarters for help and a baggage room. A machine and car-repair shed, machine shop, engine house, pattern shop, and other structures for the manufacture and repair of machinery, to the number of 10, were completed and extensive plants at Paraiso and Empire were commenced. Four commissaries, sanitary storehouses, and 1 corral were completed, together with coal chutes at Las Cascadas and Pedro Miguel, and division office buildings at Gatun and Ancon. Four clubhouses were constructed, 1 each at Culebra, Empire, Gorgona, and Cristobal.

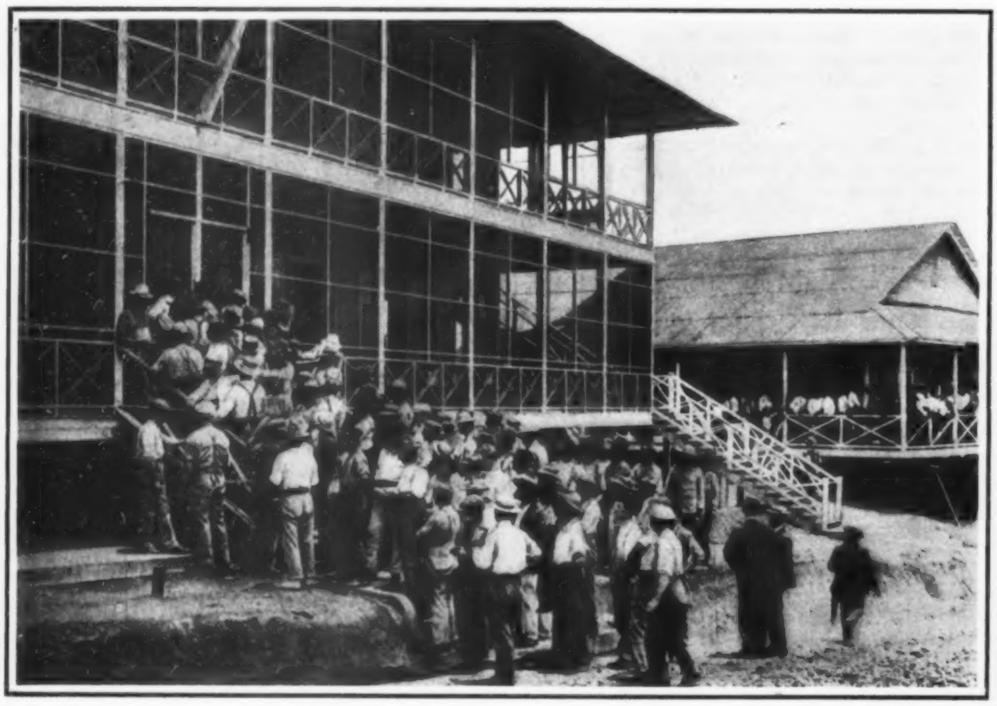
Manufacturing plants were operated at Ancon and Lirio. At the latter plant additions were made to enlarge its capacity and it is now running on full time and turning out work rapidly. The amount expended during the year on manufacturing was $276,884.19.

Of the 2,265 buildings which were received from the French Canal Company, 252 were repaired during the year and 113 destroyed. There are 678 of these buildings yet remaining to be repaired, remodeled, or demolished.

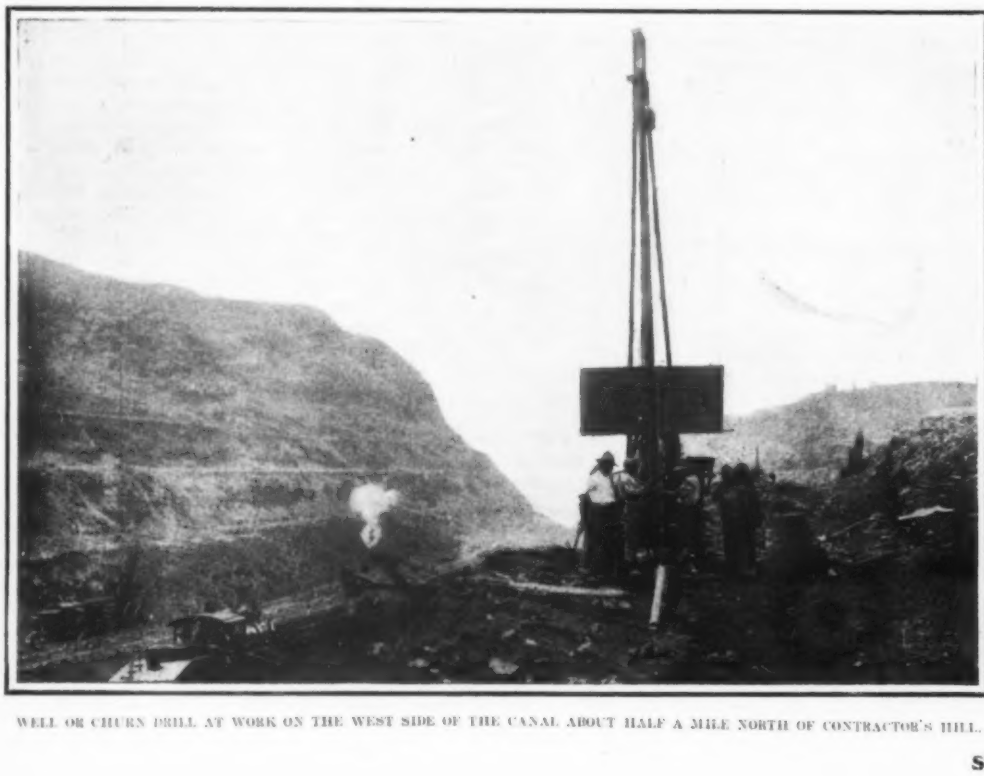
A total of 767 new buildings have been constructed up to date, and on June 30, 1907, there were on hand 2,919 buildings of all classes. Six buildings were started at Porto Bello, about 18 miles from Cristobal, for occupancy as quarters by forces engaged in stone-crusher work at that point, the product to be used for concrete in lock construction. Fire department buildings, jails, churches, post-offices, and fumigation houses to the number of 27 were constructed along the line.

The average force employed was 3,570 men, and in the work outlined above $4,357,587.57 were spent. The largest single item of expenditures was for quarters for gold employees, amounting to $1,432,415.51. The next largest item was for construction of silver employees' quarters, amounting to $482,502.88. For the construction of buildings for hospital purposes there were expended $315,196.57 and for supervision and

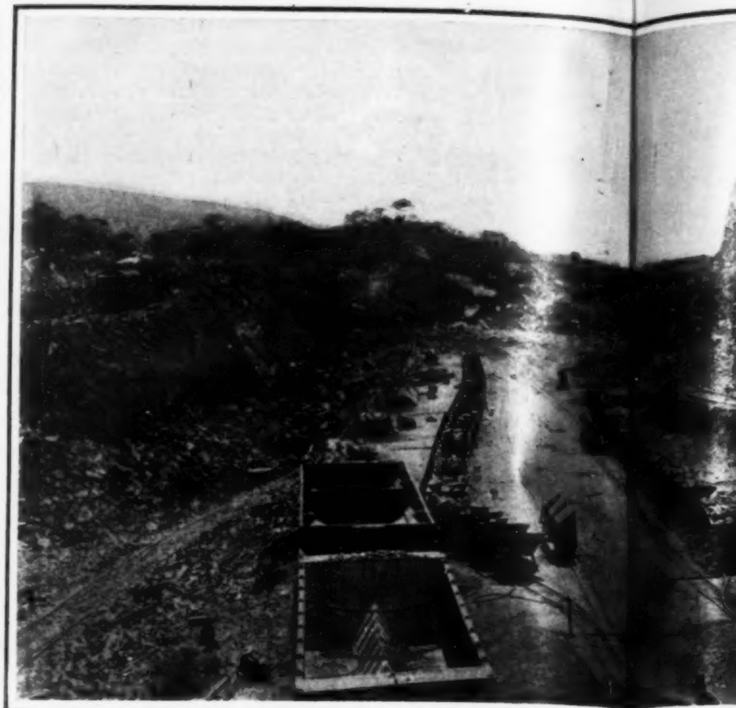
TYPICAL CAMP OF NEGRO LABORERS, PARAISO.



DINNER TIME AT A COMMISSION HOTEL, GORGONA.

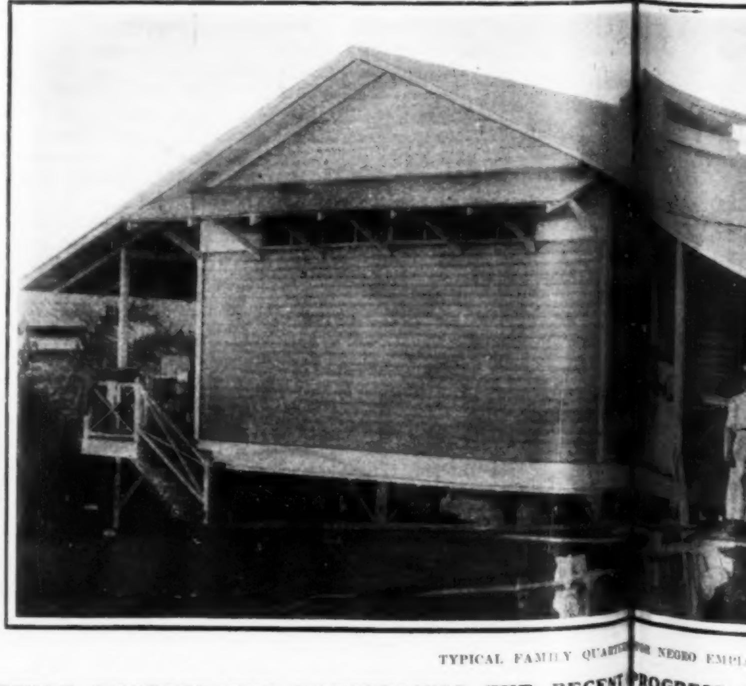


WELL OR CHURN DRILL AT WORK ON THE WEST SIDE OF THE CANAL ABOUT HALF A MILE NORTH OF CONTRACTOR'S HILL.



VIEW BEFORE BLAST WAS FIRED.

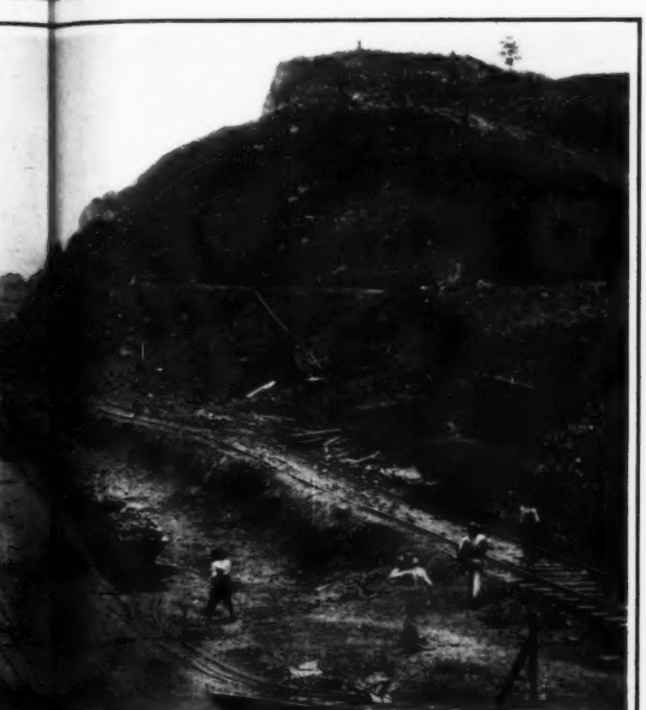
IMMEDIATELY AFTER THE EXPLOSION. BLAST FIRED SEPTEMBER 19, 1907, ON ST SIDE OF CA OF HOLES, 78 FEET; QUANTITY OF EXPLOSIVE USED, 9,600 POUNDS OF K POWDER; QU



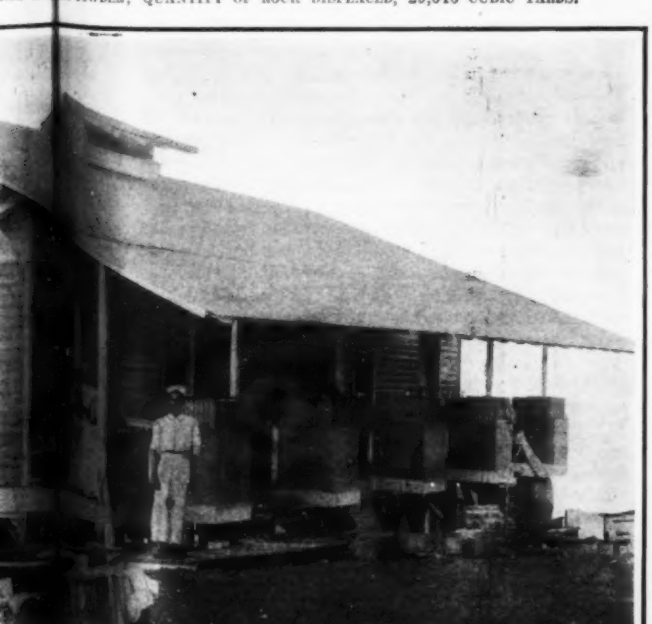
TYPICAL FAMILY QUART NEGRO EMPL

STRIKING PHOTOGRAPHS ILLUSTRATING THE RECENT PROGRESS

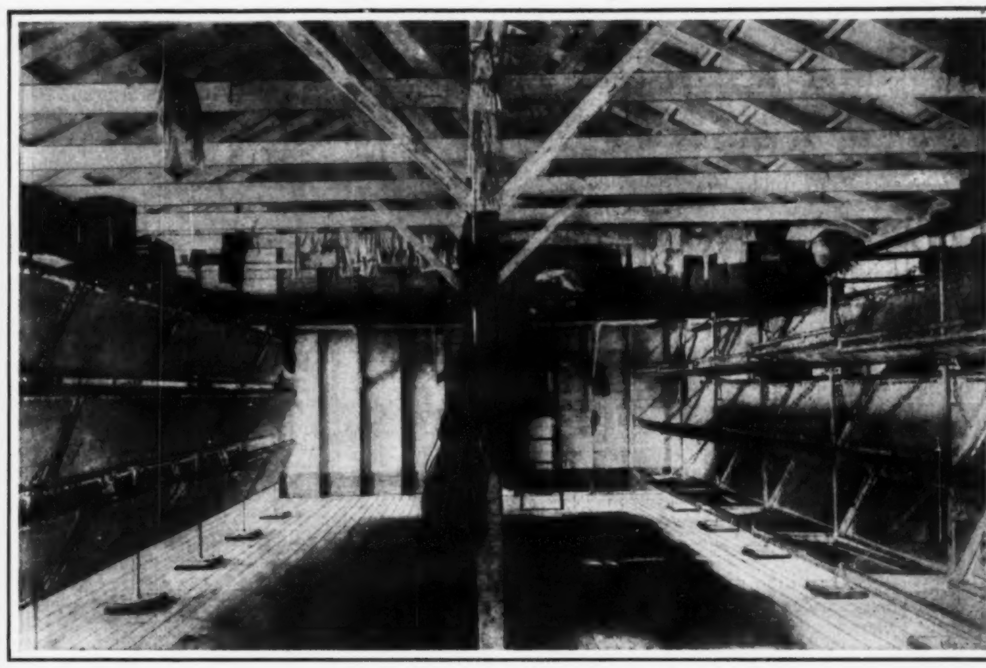
FORE BL WAS FIRED.



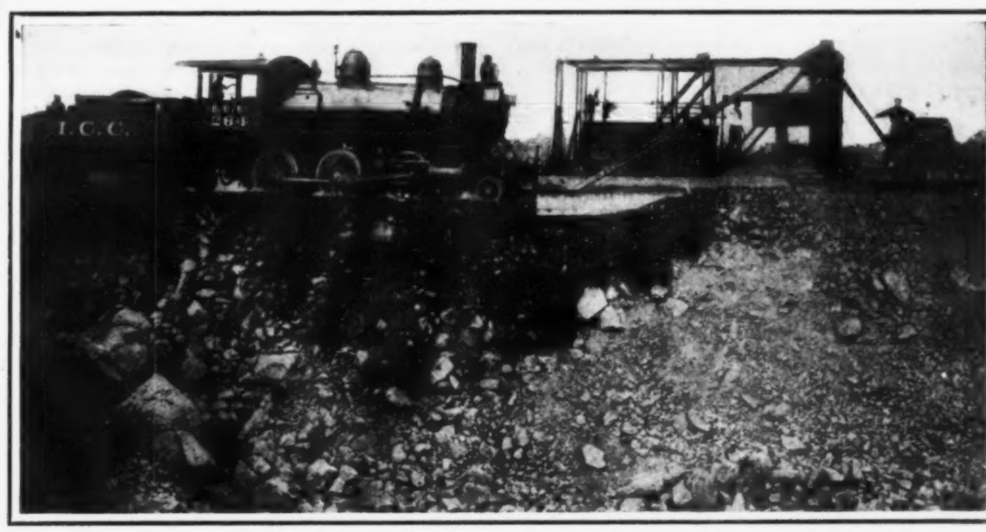
1907, ON ST SIDE OF CANAL AT BAS OBISPO; NUMBER OF DRILL HOLES, 4; DEPTH
NDS OF K POWDER; QUANTITY OF ROCK DISPLACED, 29,640 CUBIC YARDS.



QUART OR NEGRO EMPLOYEES.

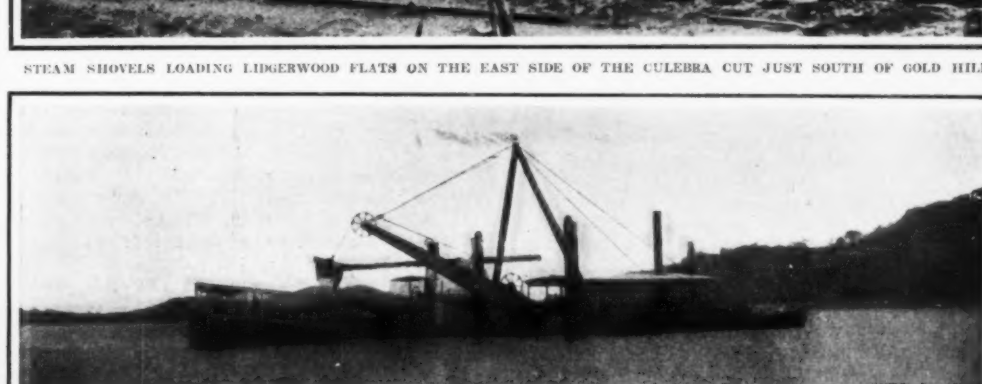


SLEEPING QUARTERS FOR EUROPEAN LABORERS.



SPREADING EXCAVATED MATERIAL ON THE COROZAL DUMP.

STEAM SHOVELS LOADING LIDGERWOOD FLATS ON THE EAST SIDE OF THE CULEBRA CUT JUST SOUTH OF GOLD HILL.



FIVE-YARD DIPPER DREDGE IN THE ENTRANCE CHANNEL IN THE PACIFIC NEAR LA BOCA. THE DREDGE IS LOADING MATERIAL INTO AN OLD FRENCH SELF-PROPELLING HOPPER BARGE, KNOWN AS A "CLAPET."

ECENT PROGRESS MADE AT PANAMA.—[See article on page 358.]

clerical force $193,763.73. These figures for construction work include both labor and material.

The division of material and supplies, the head of which reports directly to the chief engineer, is charged with the purchase and the proper handling of all material and equipment needed in connection with the construction of the canal. The diversity of the work necessitates the purchase and use of a very great variety of equipment, material, and supplies, including stock for repairs. All departments on the Isthmus rely upon this division to supply their various wants, and every effort is made to anticipate requirements by frequent purchases in the United States, based on estimates submitted by the different divisions or gaged by the rate of consumption of stock on hand at the various storehouses along the line.

During the year material was received by purchase to the value of $9,500,000, of which over 90 per cent covers purchases made in the United States. This has entailed the handling of 37 full cargoes of material and partial cargoes from about 150 vessels. Among other items there were 23,000,000 feet of lumber, 254,000 cross-ties, 4,000 piles, and about 50,000 tons of miscellaneous cargo. All material, except lumber, piling, ties, rail, and rolling stock, is received and checked at the Mount Hope storehouse, from which distribution is made to the several storehouses along the line. A large amount of old French material, consisting of boilers, pumps, Decauville track, cars, locomotives, cranes, and other material, has been repaired and placed in service. About 11,000 tons of this old French material were disposed of to dealers in the United States as scrap iron, and 4,000 tons of it were used as ballast by Panama Railroad vessels going north, when there was a shortage of commercial cargo.

Supplies are furnished to the hotels, messes, kitchens, and employees of the Commission and Panama Railroad by the commissary department of the railroad, which has developed into a modern department store. Seven branch stores, located at Gatun, Gorgona, Empire, Culebra, Rio Grande, Paraiso, and Pedro Miguel, are also in operation. In connection with the commissary there are in operation, constructed during the year, cold storage and ice plants, a well-equipped laundry and a bakery, all at Cristobal.

By executive order of November 17, 1906, sanitation was separated from the department of government, of which it was a division, and created a new department under the Commission.

The work of sanitation was carried on throughout the year, increasing in amount and extent as new engineering construction was undertaken. Its success depends upon the ability to protect employees against the malarial mosquito, and this is accomplished by draining and clearing the ground in the neighborhood of villages, in addition to proper quartering. The following, in brief, is the work done in the Zone along these lines: Brush cut, 16,000,000 square yards; swamp lands filled and drained, 1,000,000 square yards; grass burned, 30,000,000 square yards; ditches dug, 217,000 linear feet; tile ditches laid, 50,000 feet, and cemented, 50,000 linear feet. Other functions were performed in addition, such as the disposal of night soil, the removal of garbage, and the care of cemeteries.

Outside of the limits of the Canal Zone the department performed such sanitary work in the cities of Panama and Colon as was necessary to control health conditions and to keep infection from the Zone. A medical officer with a small force is established at Bocas del Toro to keep the town in such condition as to maintain quarantine against the introduction of yellow fever and to prevent the spread of it should it break out. Yellow fever has been kept out during the year.

Too much credit can not be given the department for the elimination of yellow fever, which permits the successful prosecution of the work. There was no yellow fever originating on the Isthmus during the year, though one case was brought in from shipping, the patient having passed the period of infection of the disease.

Six cases of smallpox were taken from vessels entering at Colon; one case was introduced into the city in the early part of the year from Colombia, the disease breaking out four or five days after arrival. From this 35 to 40 cases developed in Colon, but as they were promptly isolated, the people in the neighborhood vaccinated, and the houses concerned carefully fumigated, there was no further spread of the disease in the town and it did not extend to the Canal Zone.

The average daily force of skilled and unskilled laborers of the Commission and Panama Railroad was, at the beginning of the year, 19,600 and at its close 29,446. The average daily sick in quarters and in hospitals for the year was 916. So far as can be determined from such data, a comparison of the death rates among employees for the fiscal years 1905-6 and 1906-7 will show a marked improvement in health conditions during the past year, mainly due to sanitation, and also to better housing facilities and better food supplies. While death rates may be used as a basis for showing improvement in the health conditions on the Isthmus from year to year, they give no data for a comparison of this locality with other communities, because only the healthy in the prime of life are employed, and also because of the migratory character of the laborers.

THE UTILIZATION OF PEAT FOR HEATING AND THE DIRECT PRODUCTION OF POWER.*

One of the most important bases of the industrial progress of a country consists in its supply of mineral fuel. This is illustrated by the following comparison of Prussia's production of such fuel in 1865 and 1905:

	Coal.	Brown Coal.
1865......	18.6 million tons	5 million tons
1905......	113 million tons	44 million tons

The corresponding figures for all Germany, in 1886 and 1906, are:

	Coal.	Brown Coal.
1886......	60 million tons	15 million tons
1906......	136 million tons	56 million tons

In contrast to this great development of coal mining, the production and consumption of peat, which stands on the dividing line between mineral and vegetable fuel, have actually diminished. The causes of this decline are manifold. The decrease in the consumption of peat for domestic heating in Berlin, Hamburg, and other large cities is due partly to the exhaustion of the neighboring peat fields and partly to the bulky and perishable character of peat, which is greatly affected by the weather. The same causes have limited the use of peat in industries conducted on a large scale, in which economy of space and a certain and uniform supply of fuel are of such capital importance that coal is used even by establishments located in the great peat moors. The costly experiments made by the state railways of Bavaria and Oldenburg to use peat in locomotives were soon abandoned as hopeless, because of the impossibility of maintaining an adequate and properly regulated supply of steam.

Hence capitalists have shown little favor toward the numerous projects for the improvement and concentration of peat that have been laid before them and their attitude of reserve has been justified by the failure of the few projects that have been put to the test of practice on a large scale. Chemists and engineers may demonstrate, theoretically and mathematically, that improved forms of peat are equal in heating effect, pound for pound, to wood, or to the earthy brown coal that has come into extensive use in various industries, but the great bulk of peat (three or four times that of an equal weight of coal or even of brown coal) and the resultant difficulty of regulating the draft and firing would prevent the employment of peat even if it were possible to keep a sufficient store of it dry and protected from our northern climate.

It would be a waste of labor to attempt to convince the inventors, who have sought the employment of peat by physical or mechanical means, that their projects have little chance of being adopted. The only competent opinion is that of the practical man, who confronts all such plans with the question: "How much can I save on 1,000 pounds of steam by substituting peat for coal?"

* Abstract of an address by Prof. Adolf Frank to the Society for the Development of German Moors, with remarks by Dr. N. Caro.

The readiness of consumers of power to adopt new fuels that offer distinct advantages in point of economy or convenience is proved by the enormous development of the production of brown coal briquettes in northern Germany and still more by the extensive production of brown coal in the Rhine country, in the midst of the black coal fields.

Yet the opening of the vast source of energy which Germany possesses in her peat moors is a problem of great importance, for although Germany's coal deposits will probably outlast those of England, a far-seeing political economy must reckon with their ultimate exhaustion and with a progressive increase in the cost of production. Germany possesses few great waterfalls to be utilized as sources of electrical power, but her peat moors are more extensive than those of any other country in Europe, except Russia. I have long studied the problem of the utilization of this supply of fuel and I will now briefly indicate certain new discoveries that appear to promise its successful solution.

The objections to the employment of peat in large industrial enterprises are the smallness of its heating power in proportion to its bulk, the imperfect utilization of the constituents (nitrogen, for example) that have no fuel value, and the difficulty and labor involved in cutting and drying peat.

In regard to the first objection, various methods of concentrating the fuel by charring or coking have been proposed. Ziegler has succeeded in producing a very hard and pure coke, incidentally utilizing part of the nitrogen in the form of ammonia, and obtaining several other valuable products of the dry distillation of peat. But these gratifying results are secured only by the employment of pressed peat containing very little ash, so that Ziegler's process does not solve the problem of the exploitation of peat moors in general.

In my opinion the only practical solution will be found in the complete gasification of peat and the combustion of the resulting gas in explosion engines connected with dynamos. The production of combustible gas from inferior fuels in high furnaces, called generators or producers, is no new thing, and peat has been used for this purpose in iron and glass works.

Illuminating gas, which was used in the earliest gas engines, was soon found to be too costly a fuel for the production of power on a large scale. A fairly satisfactory substitute was found in Dowson gas, a mixture of carbon monoxide, hydrogen, and nitrogen evolved in simple generators. The heating power of Dowson gas is hardly one-third of that of illuminating gas, and the explosive force and maximum pressure attainable are reduced in the same proportion, but these deficiencies are easily compensated by increasing the size of the cylinder. The successful employment of Dowson gas suggested the use of the still cheaper waste gas of blast furnaces. Methods of freeing blast furnace gas from the dust and ashes with which it is contaminated were devised, and the purified gas was found so satisfactory that it is now used at blast furnaces in generating power, not only for feeding and blowing the furnace, but for many other purposes and for sale, in the form of electrical energy. The gas which escapes from coke ovens is similarly utilized. Gas engines are now made of capacities up to 5,000 horse-power. In April, 1906, 391 gas engines, aggregating 416,000 horse-power, were in operation in German mines and iron works, and many new engines were being constructed for the utilization of the gas that was still going to waste in the production of electrical energy for the supply of light and power to other industrial establishments and to cities and villages.

In England, Ludwig Mond has invented a process for the simultaneous production of ammonium sulphate and gas from waste coal, or culm. The gas, which in this case may be regarded as a by-product, is delivered in pipes to consumers for the production of heat and power.

My colleague, Dr. N. Caro, has made a further notable improvement in the producer gas industry by his patented process of gasifying inferior fuels in a mixture of air and superheated steam. Experiments made at Mond's works in Stockton have proved that Caro's process is applicable, not only to the poorest culm, but also to peat containing more than 50 per cent of water, and that such peat far surpasses coal in the yield of ammonium sulphate. Encouraged by these results, a German company has been formed for the experimental production of gas from culm and peat by the new process. A large producer plant has been erected and will go into operation next spring. The peat which will be used in our experiments is from the prism of the Marcard Canal, now in course of construction. The Irish peat used at Stockton yielded 2.8 kilogrammes (6.2 pounds) of ammonium sulphate and 250 cubic meters (8,825 cubic feet) of gas, of a heating power of 1,300 calories from each 100 kilogrammes (220 pounds) of peat (dry weight). This peat contained about 1 per cent of nitrogen. As the Marcard peat contains 1.17 per cent of nitrogen, 1 ton of it should yield 66 pounds of ammonium sulphate, worth $1.75, and 2,500 cubic meters (88,250 cubic feet) of gas, of better quality than blast furnace gas, an equal quantity of which is capable of furnishing 600 horse-power hours of energy. That peat gas is very well adapted to use in gas engines has been abundantly proved. The novel and important part of our undertaking will be the employment of crude wet peat, the consequent elimination of the great difficulty and expense of drying and pressing, and the simultaneous production of the valuable fertilizer, ammonium sulphate, which alone will insure a fair return for the great initial outlay.

Still more pleasing is the prospect of promoting the development of agriculture and manufactures in the great moorland regions of Germany, which are now

sparsely populated and imperfectly utilized. The favorable location of the great northwestern moor, in the vicinity of Bremen, Hanover, and other cities, makes possible the employment of part of the energy produced in supplying those cities with electrical currents of high tension. Other uses, notably the manufacture of wood pulp, in which Germany cannot now compete with Sweden, Norway, and Finland, because of her lack of water power, will be found for the peat of East Prussia and other districts. To me and my associates the development of a copious source of cheap power is of especial interest because it makes possible the wholesale production of lime-nitrogen.

The opening and stripping of the moors will not only bring into active employment a vast capital now lying idle on the ground, but will convert the barren moors into farming land of the best quality. Coal mining, on the contrary, often makes the surface unsafe, and transforms a fertile district into a wilderness.

At the conclusion of Prof. Frank's address Dr. Caro gave the following account of some recent experiments in the production and utilization of peat gas:

The experiments were made at Winnington, England, where there is a large plant for the production of coal gas by Mond's process. Some of the generators were adapted to the use of peat and the peat gas was discharged into the pipes ordinarily used for coal gas. The ammonium sulphate was made in the same establishment and the figures given below are actual results of experience.

The engineer in charge of the gas engine did not know whether he was using coal gas or peat gas, and he did not detect any difference in the performance of the engines. An Italian peat was used, as the experiments were made as a preliminary to the establishment of a plant in Italy. The total quantity used was 650 tons.

The peat, free from water, had approximate composition: Ash, 15.2; volatile matter, 43.8; nitrogen, 1.62; total carbon, 56.3; fixed carbon, 34.2 per cent. Its heating power was 5,620 calories. The peat was used in various conditions, but generally contained about 40 per cent of water. Each ton (dry weight) yielded 1,780 cubic meters (62,800 cubic feet) of gas of a heating power of 1,360 calories, and 118 pounds of ammonium sulphate. The gas was employed partly in generating the steam used in the gas-making process and in concentrating the ammonium sulphate, and partly in the gas engine, which produced 480 effective horsepower hours for each ton of peat (dry weight). The extraction of the ammonia facilitated the removal of dust, tar, etc., and the gas delivered to the engines contained very little tar and an almost constant proportion of hydrogen. Consequently the engines ran smoothly, without blow outs or other interruptions. Seventy per cent of the nitrogen of the peat was converted into ammonium sulphate.

The operating expenses, including sulphuric acid, repairs, and interest at 10 per cent, amounted to $1.25 per ton of dry peat, which produced ammonium sulphate worth $3.25. Hence the power was produced at an exceedingly cheap rate. Even if the revenue from the ammonium sulphate is neglected, the cost of one horse-power hour of electrical energy was less than one-eighth cent.

A SCIENTIFIC CRIME DETECTOR.

A NOVEL METHOD OF DETERMINING GUILT.

In McClure's Magazine Prof. Munsterberg, of Harvard, describes a method of detecting the innocence or truthfulness of suspected persons. He considers that by his method the police will be able to determine the innocence or guilt of a prisoner more surely than by the present "third degree" procedure. The co-operation of the suspected person is necessary, and this may seem a weak point in the method; but if it is certain in its results there will be no need for resistance on the part of innocent people, and withholding co-operation would to a certain extent imply guilt. The Professor says:

"Suppose that both my subject and I have little electrical instruments between the lips, which, by the least movement of speaking, make or break an electric current passing through an electric clockwork whose index moves around a dial ten times in every second. One revolution of the index thus means the tenth part of a second, and, as the whole dial is divided into one hundred parts, every division indicates the thousandth part of a second. My index stands quietly till I move my lips to make, for instance, the word 'dog.' In that moment the electric current causes the pointer to revolve. My subject, as soon as he hears the word, is to speak out as quickly as possible the first association which comes to his mind. He perhaps shouts 'cat,' and the movement of his lips breaks the current, stops the pointer, and thus allows me to read from the clockwork in thousandth parts of a second the time which passed between my speaking the word and his naming the association. Of course, this time includes not only the time for the process of association, but also the time for the hearing of the word, for the understanding, for the impulse of speaking, and so on. But all these smaller periods I can easily determine. I may find out how long it takes if my subject does not associate anything, but simply repeats the word I give him. If the mere repetition of the word 'dog' takes him 0.325 second, while the bringing up of the word 'cat' took 0.975, I conclude that the difference of 0.650 was necessary for the process of associating 'cat' and 'dog.' How the system works may be best seen by an actual case. An educated young man of eighteen lived in the house of an uncle. The old gentleman went to consult a nerve specialist in regard to some slight nervous trouble of the younger friend. On that occasion he confided his recent suspicion that the young man might be a thief. Money had repeatedly been taken from a drawer and from a trunk; until lately he had had suspicions only of the servants; he had notified the police and detectives had watched them. He was most anxious to find out whether his new suspicion was true, as he wanted, in that case, to keep the matter out of court, in the interest of the family. The physician, familiar with the new psychological methods, arranged that the young man come for an examination of his nerves. He then proposed to him a list of a hundred associations as part of the medical inspection. The physician said 'head,' the patient associated 'nose'; then 'green'—'blue,' 'water'—'air,' 'long'—'short,' 'five'—'six,' 'wool'—'cloth,' and so on, the average time of these commonplace connections being 1.6 seconds. But there were thirty-seven dangerous words scattered among the hundred—words that had to do with the things in the room from which the money was abstracted, or with the theft and its punishment, or with some possible motives. There appeared, for instance, the word 'thief.' The association 'burglar' seemed quite natural, but it took the boy suddenly 4.6 seconds to reach it. In the same way 'police'—'theft' took 3.6 seconds, 'jail'—'penitentiary' 4.2 seconds. In other cases the dangerous word itself came with normal automatic quickness, but the emotional disturbance became evident in the retardation of the next word. For instance, 'key'—'false key' took only 1.6 seconds, but the following trivial association 'stupid'—'clever' grew to 3.0 seconds. 'Crime'—'theft' came again promptly in 1.8, but the inner shock was so strong that the commonplace word 'cook' was entirely inhibited and did not produce an association at all in 20 seconds. In the same way 'bread'—'water' rushed forward in 1.6 second, but this characteristic choice, the supposed diet of the jail, stopped the associative mechanism again for the following trivial word. It would lead too far to go further into the analysis of the case, but it may be added that a repetition of the same series showed the characteristic variations in the region of the suspicious words. While 'crime' had brought 'theft' the first time, it was the second time replaced by 'murder'; 'discover' brought the first time 'wrong,' the second time 'grasp.' In the harmless words there was hardly any change at all. But, finally, a subtle analysis of the selection of words and of the retardations pointed to sufficient details to make a clear diagnosis. The physician told the young man that he had stolen; the boy protested vehemently. Then the physician gave him the subtle points unveiled by the associations—how he had bought a watch with the money and had given presents to his sister; and the boy confessed everything, and was saved from jail by the early discovery. The brutalities of the third degree would hardly have yielded such a complete result, nor the technicalities of legal evidence, either. In the above case the reaction-time was lengthened, in the case of the 'dangerous' words, chiefly by the subject's emotion. In the case of a hardened criminal who was warned in advance that the process would determine his guilt or innocence, the time would still be affected, but in this instance chiefly by conscious effort to avoid 'giving himself away.' In conclusion:

"The time will come when the methods of experimental psychology can not longer be excluded from the court of law. It is well known that the use of stenographers in trials once met with vehement opposition, while now the shorthand record of the court procedure seems a matter of course. The help of the psychologist will become not less indispensable. The vulgar ordeals of the 'third degree' in every form belong to the Middle Ages, and much of the wrangling of attorneys about technicalities in admitting the 'evidence' appears to not a few somewhat out of date, too; the methods of experimental psychology are working in the spirit of the twentieth century. The 'third degree' may brutalize the mind and force either correct or falsified secrets to light; the time-measurement of associations is swifter and cleaner, more scientific, more humane, and more reliable in bringing out the truth which justice demands. Of course, we are only at the beginning of its development; the new method is still in many ways imperfect, and if clumsily applied it may be misleading; moreover, there exists no hard-and-fast rule which fits every case mechanically. But all this indicates only that, just as the bodily facts have to be examined by the chemist or the physiologist, the mental facts must be examined also, not by the layman, but by the scientific psychologist with the training of a psychological laboratory."

DYESTUFFS FROM WASTE PRODUCTS.

Croissant and Bretonière in Lavalle describe a method of utilizing dyewood extracts. By heating logwood extracts to about 480 deg. F., they have obtained, in conjunction with the development of carbonic acid a black substance insoluble in water but soluble in alkali which can be precipitated with acid in brown flocculent masses; and which with various metal salts yields deposits of different colors. The same decomposition of logwood extract occurs on the addition of caustic alkalies, at a temperature of 400 deg. F., and there occurs in this case an acid which is precipitated on the addition of other acids or of metal salts. This product in its alkaline solution is a powerful dye for vegetable fibers.

If we apply the same process to other organic substances the action of alkalies produces a salt; as, for instance, oxalic acid with sawdust. The process is entirely altered if we introduce sulphur into the compounds. The sulphur may enter directly into combination with the substance or more commonly it combines with part of the hydrogen of the organic substance, liberating sulphureted hydrogen. In either case, and from nearly all organic matter new substances are obtained which will dye animal or vegetable fibers, very intensely and surely, without the aid of a mordant.

The inventors have treated a number of organic substances with simple or compound sulphide of sodium in closed vessels and found their invention invariably confirmed.

The dyestuffs are easily and certainly developed in the form of a turgid, voluminous, more or less dark colored mass, according to whether the temperature of production was higher or lower, between 400 deg. F. and 580 deg. F., and according to longer or shorter periods of heating. With the higher temperature and prolonged heating the solubility of the product increases and also its permanency as a dye. The products are very hygroscopic and must therefore be kept in well-closed tin boxes, to prevent oxidation, whereby the dyestuff is rendered insoluble; without this precaution, they will be entirely useless after the lapse of four to five months. In a freshly-prepared bath, the dissolved dye possesses such an affinity for vegetable and animal fibers that, if the dyeing process be continued long enough, it will be completely extracted from the liquor and a perfectly colorless fluid will be left. Of special effect on the richness of these dyestuffs is the character of the water used to dissolve them. In a limey water they are but incompletely dissolved and if only such water is available it must be purified before use by boiling with soda. Acids also precipitate the dyestuffs from their solutions; the precipitates, however, readily dissolve in alkaline water.—Dr. Theodor Koller in "Verwertung von Abfallstoffen aller Art."

In the Harvard Engineering Journal, J. A. Moyer gives curves of water rate or steam consumption for a 5,000-kilowatt Curtis turbine with steam of 175 pounds gage pressure, at different degrees of superheat, and one for a Westinghouse-Parsons turbine of 400 kilowatts with steam of 150 pounds under similar conditions, and for comparison theoretical curves for approximately the same limits as in these cases. In this diagram one line represents the theoretical steam consumption calculated from the energy available from the adiabatic expansion of 1 pound of steam, using 0.48 for C_p. Another line gives the curve using the values of C_p ascertained by Knoblauch and Jakob, and Lorenz, which gives considerably lower values for water rates. Another diagram gives the economy of steam due to superheat on a percentage basis. The gain in steam economy is shown to be due in part to (1) economy of the energy in the steam, and (2) superior mechanical operation. A diagram shows the percentage reduction of rotation loss in superheated steam. A combination of impulse and reaction types is recommended for the best results.

A SUCCESSFUL FARM MOTOR.

THE AUTOMOBILE ADAPTED TO AGRICULTURE.

BY C. M. EASON.

The most conspicuous features of this machine, which has been named the Autotractor by its inventor, Ansel S. Wysong, are its light weight, ease of control, and simplicity. These are made possible by the use of a very effective system of chain transmission, together with a very simple engine carrying the friction clutch and sprocket bearings on its crank-base casting, and a steering arrangement somewhat similar to that used in automobiles.

There have been several models of the autotractor built during the past three years, and a larger machine is now under construction, which is expected to produce better results than its predecessors. In various tests both in plowing and harvesting the autotractor has been found to be more economical than either horse or steam power. Practically any liquid fuel may be used, and there is no limit to the uses to which it may be put, from threshing grain to pumping water. The Topeka Foundry and Machine Company are builders.

The 6-horse-power machine shown with 6-foot binder was the first successful model built, and it was followed by a 15-horse-power machine.

On the road the autotractor is well adapted to all kinds of freighting and general road work, and has advantages over the steam traction engine, for there is no fireman, no coal wagon and driver, and no water wagon. This last is a big advantage. Under average conditions the saving effected by the autotractor will amount to from 30 to 50 per cent of the cost of operating a steamer.

The difficulty of slipping has been overcome by the use of sharp lugs on the wheels, and by so balancing the machine that when under load practically all of the weight is carried by the drive wheels. The machine shown in the illustration pulled six heavy moldboard sod plows four inches deep in dry buffalo sod in western Kansas, which is a heavy load for twenty horses, this type of plow being of heavier draft than those used with horses. The wheels held perfectly except in "wallows" or muddy spots. Although a heavy load may be pulled on good ground, it is more effective to pull a few plows at a high rate of speed, with special moldboards, if necessary, thus giving plenty of traction to cross mud or sandy spots, where the machine is in the slippery ground while the plows are still cutting firm soil.

The large autotractor now under construction will combine the main features of the earlier machines with a great many improvements. Its main features are the same as those of the preceding types, with the exception of the differential gear, which is so made that by changing a sprocket the balance will be thrown to any position on the hitch beam, thus allowing the machine to stay on the hard ground, even when pulling subsoil plows, while with the ordinary arrangement the balance of power is always at the center of the beam, making it necessary to pull plows which will turn as much as the width of the machine or to run one wheel of the traction engine on the plowed land, which makes effective work impossible.

In the accompanying sketch the engine is shown with a cross-section of one pair of cylinders, *A* and *B*, which are cast together with an air chamber between. A light valve is placed in head of cylinder *A* and connected with carbureter. A similar valve is placed in air chamber at intake port of cylinder *B*, which is balanced with the carbureter valve in head of cylinder *A*. Cylinder *A* is connected with the air chamber near the top, and is at all times in communication with the air passage. Beginning with the suction stroke of cylinder *A*, the air passage between the cylinders is filled with combustible mixture. Cylinder *A* draws this mixture back into its compression space, while pure air follows through the valve at intake port of cylinder *B*, filling the air chamber. The valve from carbureter, being of equal spring tension and capacity, admits an equal amount of mixture to cylinder *A*, which is then fully charged with the firing mixture. Cylinder *A* now compresses the gas in its chamber and the air in the passage to about 15 pounds per inch, when the piston in cylinder *B* opens the intake port *C*, Fig. 2, which allows the pure air from the passage to rush through cylinder *B*, blowing the burned gas out through the exhaust port, and followed by the gas mixture, which fills cylinder *B*, and is compressed and burned in the usual way, when the cycle is repeated.

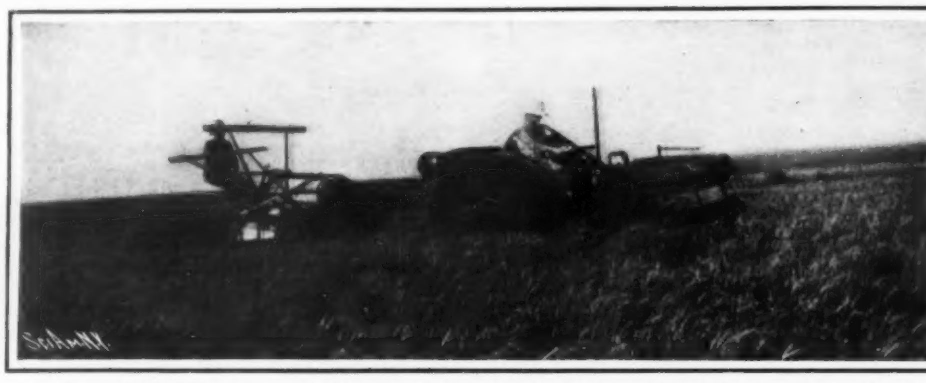
The capacity of cylinder *A* is equal to that of cylinder *B* plus the amount of air to be used in blowing the gas from the cylinder *B*.

The pure-air pipe and the carbureter are joined to the supply pipe, which takes all the air used from above the canopy.

The connecting rods are of manganese bronze and divided laterally, the object of this being to reduce the strain on the bolts. The cylinders are 7 and 8½ inches by 8-inch stroke, the crank shaft 3 by 3½-inch wrist, running in bearings of Parsons white brass.

All crank-shaft bearings are on the crank-base casting. The spark timer is of red fiber mounted in a brass housing which gives it means of oscillating to time the spark. One tool steel block is set in a flange in the shaft, flush with the surface of a fiber ring. Two contact brushes are held against this ring by the fiber block in the brass housing. The whole timer is self-contained, being made very large to resist wear, and having no small or delicate parts to get out of order. Connection is made to the steering post in the same manner as in automobile practice. The carbureter is so formed as to control the pure air as well as the mixture, and is operated by a governor which automatically prevents the engine from racing when the plows are suddenly thrown out of the ground at the end of the field. The gasoline supply is from a 70-gallon tank in the rear through a strainer and copper tubing to the carbureter. Air supply is from above the canopy to the carbureter through a thin 4-inch tube.

The exhaust is taken from the two firing cylinders into a cast-iron manifold, which holds a 5-inch casing, into which is set the exhaust pipe. This pipe has sawed slits extending over the portion inside the casing, and is carried up through the canopy, where it is again slotted to silence the exhaust.



A SIX-HORSE-POWER MACHINE WITH A SIX-FOOT BINDER HAS CUT AND BOUND TWELVE ACRES OF WHEAT IN FIVE HOURS.

Lubrication is effected by a bank oiler located on the radiator, where it is kept at practically the same temperature in hot or cold weather. The pistons are oiled directly from the oiler, and the cranks by splash. There being no mechanically-operated valves, the problem of lubrication is very simple, the bank feeding only four tubes. Large handhole plates are provided for the inspection of connecting rods and bearings, and all parts are made as accessible as possible.

After a good deal of experimenting the form of radiator adopted is that shown in the photograph of the large machine, and consists of a steel tank mounted on the front of the machine over the steering wheel, and filled with tubes, there being ninety tubes of 2 inches diameter by 4 feet in length. Through the center of the tank runs a shaft, upon which are mounted two fans, one at either end of the tank, the circulating pump, and the drive pulley, which is at the opposite end of the tank from the pump.

The circulating pump is of large diameter, and is a plain centrifugal type, running in either direction. The pump is designed to draw water from ponds or tanks for filling the water tank at the rear, and is provided with a special valve which connects the piping for filling the tanks, drawing the water from tank to radiator, or for circulation through the cylinders.

The autotractor is provided with two clutches, one for belt drive and one for transmission to chain gearing, which takes power from the heavy flywheel and transmits to the sprocket through a sleeve over main shaft. This clutch is two-jawed, carrying a wooden face for friction surface, and acts on the inside face of flywheel. By this system the machine can be jerked out of holes by the momentum of the flywheel, without shock to the engine and shaft. On the pulley end of the shaft there is mounted a light flywheel, outside of which is an ordinary gas-engine friction-clutch pulley.

The chain transmission has been found to give good service. The chains are of the steel-roller type, of 1½ and 2-inch pitch, with a breaking strength of 50,000 pounds at the back wheels.

The countershaft is mounted on a superstructure which also carries the seat, and is fitted with a pair of steel sprocket rims of 86 and 89 teeth respectively, these rims being supported by a web of boiler plate and held apart by a light cast-iron ring through which the rims are bolted together. On the opposite side from the boiler-plate web is a thin sheet-steel web, which forms a dustproof covering for the differential gearing, which is mounted between the two webs.

The two sprocket rims correspond with the two small sprockets on the clutch sleeve and carry one chain, of 1½-inch pitch, which is thrown from one set to the other for change of speed ratio.

Upon each end of the countershaft is mounted a solid steel sprocket of 11 teeth, which corresponds with one of 69 teeth mounted on each hub of the driving wheels, and carrying chains of 2-inch pitch.

The drive wheels are 5 feet 10 inches in height, and are 36 inches in width. The tires are formed of steel plate 38 inches wide, flanged in 1 inch to stiffen each edge. The hubs are of cast iron, cored out and ribbed inside to combine lightness and strength, and

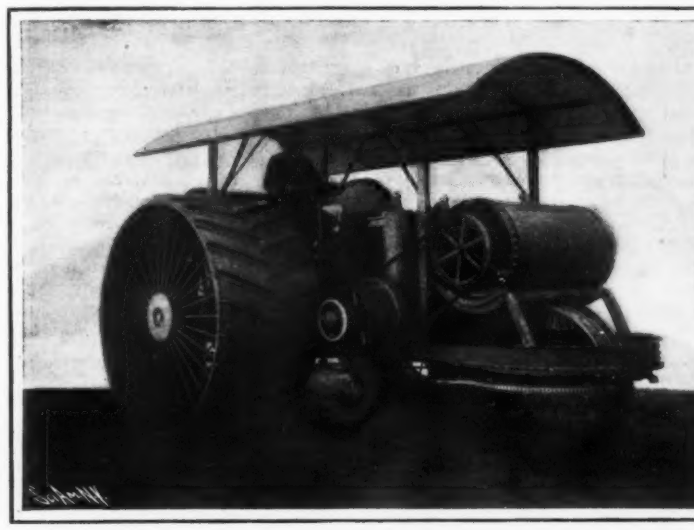
A FIFTEEN-HORSE-POWER MACHINE WITH SIX PLOWS CUTTING EIGHT FEET OF SOD AT A SPEED OF FOUR MILES AN HOUR.

A SUCCESSFUL FARM MOTOR.

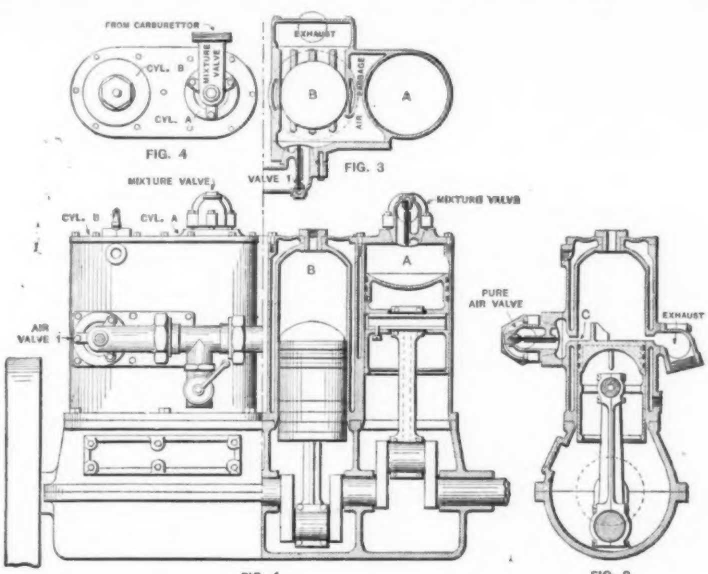
carry a large sprocket web on the inner end which is held in place by studs.

From the rim of the large sprockets on the hubs are extended steel bars, which are fastened to the rim of the wheel and take all the pulling strain, thus relieving the spokes of all torsional strain.

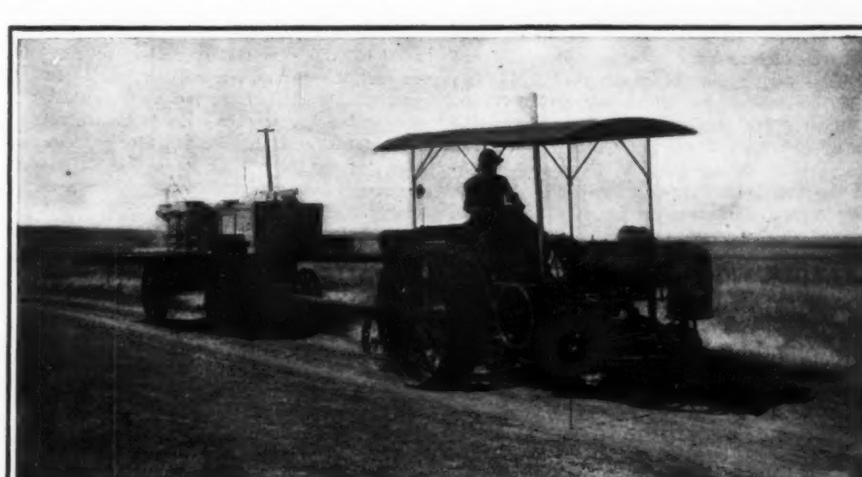
The front wheel is made in the same manner as the drive wheels, and carries a skid band of 2½-inch T section.



THE NEW MODEL AUTOTRACTOR.



THE AUTOTRACTOR ENGINE.



THE AUTOTRACTOR AS A ROAD LOCOMOTIVE.

A SUCCESSFUL FARM MOTOR.

THE MANUFACTURE OF ORGANS.*

The manufacture of the reed organ, like that of other musical instruments, is largely the result of experience and development. Probably the manipulation of the tongue of the reed to a proper size and curve and the determining of the size of the reed cells, etc., and the length and size of the qualifying cells, when such are used, are the most delicate of the intricate operations involved in its manufacture.

The vocalion is a reed organ approaching somewhat a pipe organ in its characteristic tone quality. Vocalion instruments are largely used in churches, and usually have a pedal base and often two manual claviers, or keyboards, conforming in appearance to the pipe organ. The difference between the ordinary reed organ and the vocalion is that in the latter the air current passes through qualifying cells and tubes before or after reaching the reeds.

There have also been manufactured a combination pipe and reed organ, desk and reed organ, and other somewhat unusual compound forms of the instrument. Almost all the materials used in reed organ construction are strictly American products, with the exception of ivory and ebony. Very little ivory is now used on the keyboard of reed organs, celluloid being substituted in its place, while a stained wood is generally used instead of ebony for the black keys. Very little expensive veneer is used on these instruments, unless by special order, as it greatly increases the cost of the instrument. Unlike the averago piano manufacturer, organ makers usually manufacture all parts of their instrument with the exception of reeds and keys, the making of which is really a separate industry.

The number of pipe organs manufactured is not great, but as a rule they are large and comparatively expensive. Their production is not centered to a very marked degree in any one State. The value of the organs produced in Massachusetts at the census of 1905 formed 24.9 per cent of the total value for the United States. Boston is one of the chief centers for the manufacture of high-grade pipe organs, 60 of these instruments having been built in this city during 1904, with a value of $313,220, a greater valuation than was reported by any other State.

The pipe organ is often spoken of as being the largest, most expensive, and most perfect of all musical instruments, and the methods of its manufacture are of considerable interest. Almost every pipe organ is practically built to order to accord with the architecture or acoustic qualities of the room or auditorium in which it is designed to be placed. The ornamental work of the pipe organ is sometimes put in by the building contractors, who are in no way identified with the organ builders.

One complete stop of one rank of pipes in the modern organ consists of 61 notes for the manual clavier and 32 for the pedal clavier, and there are as many stops as may be desired according to the size and cost of the organ; in some instances there are 100 or more. These pipes are made of wood or metal, the wood being carefully selected of various growths, and the metals, chiefly zinc, tin, and lead, being used in alloys according to the different qualities of tone desired. The arranging of the shape and size of the pipes is an operation in which experience and knowledge on the part of the builder are necessary to the manufacture of a successful instrument. The voicing and tuning of these pipes are invariably done before they are set up in the organ, and this operation is of great delicacy. Final tuning and regulating are done after the pipes are placed in the finished instrument.

The bellows of a pipe organ must be of exactly sufficient capacity to feed all the pipes, and therefore varies in construction according to the size of the organ. The operation of the bellows may be by hand, by hydraulic power, or by electricity, in which latter instance a current of from 100 to 200 volts in strength is necessary. There is an electric fan feeder recently patented which is said to be very successful in operation and which takes up much less room than the ordinary class of feeders, but the ordinary compound bellows is used in the majority of organs, and almost altogether in those built in 1904. The air does not pass directly to the pipes, but is generally led first into a regulator bellows, which makes the pressure more even and regular in strength, after which it is conveyed to the wind chest, and is then caused to pass into the pipes by the opening of valves controlled by the key or playing mechanism.

Probably the most recent development in pipe organ construction is the electric action, which is operated either by a storage battery or by a small generator connected with the bellows motive power. Depression of a key causes electrical contact, allowing the current to pass through a magnet in the wind chest or pallet box, which magnet operates a primary valve connected with a larger valve, which, being open, allows passage of air, thereby causing the pipe to speak. Each key of both manual and pedal claviers is fitted with this arrangement of magnet, air cells, valves, etc., and the action is simultaneous with the pressure on the key or pedal. The use of electricity in the action mechanism allows the instrument to be played with an even and light pressure on the keys, whereas, in the older style tracker organ, to operate some combinations required considerable strength. Another advantage in an electrically operated organ is that the key case, or console, may be placed at any distance from the organ proper, inasmuch as the power is transmitted by wires to the valve mechanism connected with the pipes. This arrangement is also possible in the tubular pneumatic organ, although the distance capable of being covered is necessarily somewhat limited.

* Abstracted from a bulletin issued by the United States Census Bureau.

In a newly patented wood-distilling apparatus the wood, contained in a crate, is lowered into a vertical retort set in a furnace, and the top of the latter is closed. Steam is passed through a "fire-screen" around the retort, and becomes superheated; it is then admitted into the upper part of the retort through a number of nozzles. The steam, along with the products of distillation, escapes from the bottom of the retort through a pipe. The crate is divided into upper and lower compartments by a slatted partition, under which troughs are arranged to convey the products of distillation from the upper half of the crate on to the inclined bottom of the retort.

THE AGE OF THE EARTH'S CONSOLIDATION.

HOW SCIENTISTS ESTIMATE PERIODS OF TIME.

BY T. J. J. SEE.

THE assumption of an original uniform temperature for the earth is only a first approximation to the true condition, not justified by a closer examination of the subject. The mathematical theory of the heat distribution in a gaseous globe shows that the temperature increases rapidly toward the center, and hence falls off correspondingly near the surface. Relatively to the average temperature of the whole mass, that of the surface is very low, and that of the center quite high. This is the condition in a gaseous sphere, and it seems certain that it cannot be greatly modified by the surface cooling which leads to incrustation. This latter arises mainly from resisted circulation, and retarded supply of heat from the under layers, as the surface density increases. Prior to the beginning of surface cooling the planet passes through a stage of maximum temperature, and heat is both radiated and conducted through to the outer layers; but eventually the resistance to propagation of heat becomes so great that a fall of temperature is inevitable. In the case of the earth there is excellent reason to conclude that the surface temperature never much exceeded 2,000 deg. Fahr.

The experiments of Profs. Rücker and Roberts-Austen at the Royal College of Science, London, on basalt or dolerite, showed that this rock was completely fused at 1688 deg. Fahr. Basalt is a typical rock of the earth's crust, prevalent in nearly all volcanic districts; and it seems probable that a temperature of 2,000 deg. Fahr. would therefore not only fuse all the principal rocks of the earth's surface, but also reduce many of them to a state of vapor.

The fact that the other planets of our solar system are not at present self-luminous, though the larger masses are known to have high internal temperature, tells against the theory of a very high surface temperature also in the case of the earth. For although we view the other planets at only one stage of their existence, and therefore cannot fully judge of their conditions at other cosmical epochs, yet the absence of self-luminosity when so much heat is known to be stored up within these planets can only indicate that a great lowering of temperature always takes place near the surface, as is also true in a sphere of monatomic gas. Thus, it is not probable that even at the maximum the surface temperature of such masses would be very high. Lord Kelvin has estimated the temperature at 7,000 deg. Fahr., but there are clear indications that this is much too great, and in all probability we shall not be far wrong in using 2,000 deg. as the most acceptable value in all calculations on the secular cooling of the terrestrial globe. The temperature will increase with the depth, but for a shallow layer we may take it to be uniform; the temperature of 2,000 deg. then would not correspond exactly to the surface, but rather to the average of a thin sheet forming the boundary of the molten mass. As the outer layer was no doubt agitated from beneath, it would both lack in uniformity of temperature, and also be constantly changing, so that a mean temperature of 2,000 deg. Fahr. seems to be the closest approximation we can make to the true conditions.

Considering the earth to be a sphere of the same conductivity as ordinary rock, we can mathematically calculate its age since its crust first formed. Lord Kelvin, on an assumption of a crust of 7,000 deg. Fahr., calculated the age of the earth as 101,673,000 years. Following his calculations, but estimating the crust heat at 2,000 deg. Fahr.—which is now agreed on as a more probable figure—we get an age of 8,302,210 years. Accordingly, we conclude from this that the age of our incrusted planet can scarcely exceed ten million years, which accords very well with the duration inferred from the theory of the sun's heat.

The Rev. O. Fisher has developed another method for calculating the age of the earth, based on a consideration of the thickness of the crust and its gradual loss of heat. Considering the thickness of the crust as 17.5 miles, which is very near the thickness indicated by the San Francisco earthquake, the age of the earth appears as 5,262,170 years. Fisher, however, calculates the crust as not exceeding 21.91 miles. Taking this latter figure, the age of the earth is found to be 8,248,380 years.

This agreement with Lord Kelvin's figures is the more interesting since the Rev. O. Fisher cannot reconcile it with what he has hitherto thought the approximate age of the earth, and he endeavors to explain it away. He says:

"This is a far shorter period than geological phenomena appear to require, for although it is not possible for them to assign any definite limit to the world's age, we can form some idea of an inferior limit which it must have exceeded. Sir A. Geikie thinks that the stratified rocks alone, which contain organic remains, cannot have taken much less than 100 million years for their formation."

He then proceeds to examine the hypothesis of an energetic substratum, and by this process reaches a greater age for the world. But the hypothesis of an inert substratum is obviously the proper one. For the substratum is shown to move only under the throes of an earthquake, and no circulatory movement of lava exists even just beneath the crust. Hence we adhere to the result there obtained, and must consider the significance of the small age of the earth. It will be seen that for a thickness of 22 miles, the age of the earth's consolidation is almost exactly the same as that reached by the use of Lord Kelvin's formula.

The result found by Lord Kelvin's method rests upon the observed rate of increase of temperature downward, namely, 1 deg. Fahr. for 51 feet, which is about the same as the value used by Fourier nearly a century ago, and not improved upon by the deep borings made in recent years. It also rests upon the assumed surface temperature of 2,000 deg. Fahr., which probably is comparatively near the truth. Is it purely an accidental coincidence that with these data one is led by the Fourier-Kelvin formula to an age of 8,302,210 years, while by Fisher's formula, depending on the thickness of the crust essentially verified by earthquake phenomena, one finds the almost identical age of 8,248,380 years? Moderate variations of the data might derange this excellent agreement somewhat, but probably no change of the constants within admissible limits would produce extreme discordance in the resulting ages of the earth. It seems, therefore, difficult to escape the conclusion that these figures really approximate the true age of our incrusted planet. At least the period since the consolidation is of the order of ten million years.

Different investigators will naturally form different estimates of the age of the earth as found by the several different methods of approximation; but it is difficult to see how the larger values formerly current can be justified by physical research based on the propagation of heat involved in the secular cooling of the globe. The writer has not the geological learning requisite for the use of the methods based on sedimentary rocks and their deposits of organic remains, but it seems very doubtful if these methods can lay claim to even approximate accuracy; and to most minds the conclusions drawn from the physical methods will naturally carry much greater weight.

Some considerations, however, based on the probable average rate of the elevation of the Andes, taken at only one-tenth of an inch a year, or ten inches in a century, seem to show that the age of these mighty mountains need not much exceed three million years. In the case of the mountains west of the Rockies a numerical estimate is not quite so easy, but it is doubtful if anything authorizes an estimate exceeding five million years. In this immense period the whole country west of Laramie may have been raised from the sea; in fact, this is indicated by the abundant fossils of saurians in the beds of Wyoming, as well as by the numerous parallel ranges of mountains in Nevada and California, showing the successive recessions of the sea. One is led, therefore, to think that, after all, our consolidated globe may not have an age exceeding eight or ten million years. In comparison with the brevity of human history, such periods are almost infinite; and so little is known of the rates of variation of organic species under the unknown conditions of the past, that we may well hesitate before assuming longer periods for the life of our incrusted planet.

In contemplating this result we are again confronted with the question of the cosmical significance of radium. Several years ago, when the enthusiasm over the radium discoveries was at its height, there were those who admitted a terrestrial history of a thousand million years. But mysterious as radium still remains, it is doubtful if such a view is generally held to-day. It is a remarkable fact that the more we study radium, the less we seem to really understand the part it plays in cosmical processes. So far, at least, there is no proof that it exerts any sensible influence, except possibly in chemical transformations.—Abstracted from Popular Astronomy.

THE BEAUFORT SEA.

THE vast archipelago reaching from the vicinity of Greenland westward to the boundary line which touches the continent 400 miles east of the eastern boundary of Alaska incloses an area which was explored by Capt. Einar Mikkelsen and Mr. Ernest Leffingwell, some one or two years ago. An account of the expedition has been published in the Bulletin of the American Geographical Society. The northern edge of this group slopes away from Grant Land in latitude 83 to Prince Patrick Island, a short distance above the 77th parallel, and the region of which we speak, concerning which little or nothing was formerly definitely known, lies between the archipelago and the land extending northward to Bering Strait. It is called Beaufort Sea by geographers, owing to their belief that there is a practically unbroken stretch of ocean from Alaska to the pole. The plans of the expedition unfortunately miscarried, and it was impossible to set up winter quarters on the western edge of the archipelago in Bank's Land. If this depot had been established, a sledge journey would have been made afterward in a westerly direction from Prince Patrick Island, during which soundings through the ice could have been made, showing whether or not water existed underneath. Owing to the necessity of abandoning the vessel at Flaxman Island near the Alaskan coast, the sledges of the party were driven nearly 100 miles from the continent, during which journey the inquiry regarding the depth of the sea was carried on. It was found that for two-thirds of the distance the water was shallow. It then suddenly deepened, and with more than two thousand feet of line out the bottom could not be reached. This led to the inference that the "continental shelf" extends not more than sixty miles from the coast. It is held by many geographers that it is hopeless to look for large islands in the Arctic Ocean after the continental shelf has been passed; they would feel that the existence of water was determined if the position of the boundary of the continental shelf could be accurately determined. There is, of course, a slight chance that Capt. Mikkelsen followed a "submarine valley" and had not left the true continental shelf. Much of the ice traversed was of a variety seldom formed except in a landlocked sea, while certain peculiarities in the set of the currents indicated the probability of the existence of a barrier to the eastern of the path to be followed. This makes the finding or the discovery of a large island in Beaufort Sea, while not absolutely removed, a very remote possibility.

KILLING OFF OUR BIGGEST BIRD OF PREY.

TO-DAY the California condor—the largest bird of prey inhabiting the United States—is represented by a miserable remnant lingering in southwest California; its distributional area, once extending as far north as the Fraser River in British Columbia, is now a mere dot on the map.

In the old days it abounded every spring on the Columbia River, feeding on the salmon cast up on the shore. It hung round the Indian villages for the sake of the offal thrown away, and, together with ravens and turkey buzzards, visited the water-falls and cascades of the salmon rivers. The fish, being obliged to take leaps at these places in their progress along the stream, often landed themselves high and dry among the bushes, and thus provided a meal for the expectant condors. The present species also fed on carrion, and was very voracious. When on the ground this condor walked with a strut, like a turkey, but was obliged first to run or hop several yards before launching itself into the air. Once on the wing its flight was slow, steady and graceful, its noble proportions dwarfing the turkey buzzards in the same valley to mere swallows.

"Their quills are used by the hunters for tobacco-pipes," observed Mr. David Douglas many years ago. "Recently the Mexican and Indian gold-seekers have well-nigh exterminated the California condor for their magnificent hollow quills, which afford rough-and-ready purses for carrying gold-dust!"—The Zoologist.

THE WORLD'S PRODUCTION OF COAL.

THE world's production of coal in 1906 amounted to about 1,106,478,707 short tons, of which the United States produced 414,157,278 tons.

Since 1868 the percentage of the world's total coal produced by the United States has increased from 14.32 to 37, and this country now stands far in the lead of the world's coal producers. In 1906 the United States produced 43.7 per cent more coal than Great Britain and 85 per cent more than Germany. Exclusive of Great Britain the United States in 1906 produced more coal than all the other countries of the world combined.

It is interesting to note that 96 per cent of the world's coal production is mined north of the equator. Australia is the only continent lying entirely to the south of the line. More than half the area of Africa lies to the north, and Europe and Asia are entirely north of the line.

THE EUCALYPTS OF AUSTRALIA.—II.*

RECENT WORK ON THE EUCALYPTS.

BY HENRY G. SMITH, F.C.S.

Concluded from Supplement No. 1665, page 351.

The following are the main points in the evolution of these kinos as shown by the chemical products of the several species. It can be demonstrated that the alterations which have taken place have been contemporaneous with those in the oil constituents, and also in the venation of the leaves. Two well-defined crystallized products are found in these kinos—aromadendrin and eudesmin. In the exudations of what appear to be the earlier members of the genus, aromadendrin occurs alone, eudesmin being quite absent. I have also isolated aromadendrin from the kinos of *Angophoras*, where it occurs alone without eudesmin, so that in this direction these trees are shown to be allied to the older members of the genus *Eucalyptus*. This is also true of the venations, and the venation of the leaves of *Angophora lanceolata* and *E. corymbosa* have a striking resemblance to each other. The principal difference between the two trees is the absence in Angophora of the operculum in the bud stage.

As the several eucalypts descend toward the more recent species, the second body—eudesmin—makes its appearance. It then commences to displace the aromadendrin, until at the end of the group known as the "boxes," eudesmin is the principal crystallized substance present.

I have not yet examined a eudesmin-bearing kino in which aromadendrin does not also occur, so that commencing alone in the kinos of the earliest members of the genus, it runs through the whole group of species whose kinos contain crystallized bodies, although at the more recent end it is present in very small amount. These two bodies can be separated in a pure condition when they occur together in any kino. They show a remarkable difference when treated with strong sulphuric acid and with nitric acid, as they give the reverse coloration with these acids, so that it is easy to detect even slight traces of each with the other. The tannins in all the kinos containing these bodies give a greenish or a blue coloration with ferric chloride.

Another group of these trees, which branches off in a different direction to the "Boxes" and the "Gums," includes the "Stringybarks," and the "Peppermints." The exudations of this group do not contain crystallized bodies, and the tannins give a violet coloration with ferric chloride. They are very astringent, relatively the most astringent of all eucalyptus kinos, but the tannins act very indifferently with raw hide substance. They are, when fresh, entirely soluble in alcohol and in water.

Another group of eucalypts, known as "Ironbarks," exudes a handsome looking kino, clear, bright, and transparent when fresh, but this soon changes, the kino ultimately becoming almost black. Although readily soluble in water, yet the kinos of this group are almost insoluble in alcohol. This peculiarity was long thought to be due to the presence of a gum, but I recently showed that this was not the case, but that this insoluble substance was a tannin glucoside. It has been named "emphloin." It is a remarkable substance, the sugar group being particularly interesting. These kinos give a brownish-gray coloration with ferric chloride, but a violet with ferric acetate. The tannin seems to be identical with that of the "Stringybark" and "Peppermint" groups. The distribution of the kinos in the plants themselves is also often dissimilar. In the "Stringybarks" and allied species the astringent substance is often distributed through the wood, and in many other species this is the case also, causing the timber to be of indifferent quality owing to the rings of kino. In the "Ironbarks" the kino is often largely distributed throughout the bark itself. The barks of these trees are often very thick and rugged, and contain a large amount of kino. There are enormous quantities of this bark in Australia, and if some method of utilizing it satisfactorily for tanning purposes could be discovered, the result would be of considerable advantage. It has already been used to some extent, and much effort has been expended in the endeavor to utilize it, but it is very sluggish in its action on hide, and forms a dark reddish-colored leather.

The eudesmin-bearing kinos appear to be the best for tanning purposes if found in quantity, and the barks of those species exuding this class of kino are often rich in tannin, as the "Mallet," *E. occidentalis*, for instance. The oils from species containing eudesmin in their kinos do not appear to contain phellandrene, and those species which exude kinos in which eudesmin is found in quantity, contain the largest amount of the aldehyde aromadendral in their oils. The kinos of the species, which yield oils rich in eucalyptol, all resemble each other, and all appear to contain eudesmin in small amount. This substance has been isolated from the kino of *E. Smithii*, perhaps the richest of all the eucalyptol bearing species.

In certain species belonging to this class of trees, the kinos of which contain eudesmin, a sugary substance often exudes in some quantity; this is known as "eucalyptus manna." It is obtained in some quantity from *E. viminalis*, and in smaller amount from *E. punctata* and other allied species. The principal sugar is raffinose. I am not aware of any record of sugary exudations having even been obtained from any eucalypt the kino of which contains the glucoside emphloin, nor in any species containing an identical tannin. This is suggestive of the possibility of raffinose itself being allied to the glucosides, and it behaves similarly to the synthetically prepared disaccharides of Fischer and Armstrong which also resemble glucosides.

The "kino red" of the glucoside obtained from all the "Ironbarks" as *E. crebra*, *E. paniculata*, etc., as well as from the kinos of the "Stringybarks," as *E. macrorhyncha*, etc., and the "Peppermints" as *E. piperita*, etc., when boiled with acid all give photocatechuic acid, and catechol when fused with potash. They all give identical colors with mordanted cloth, similar reactions with reagents which act on the tannin alone, and the tinctures gelatinize with equal rapidity. From the products of decomposition two of the hydroxyls in the tannin molecule are in the ortho position relatively to each other, and the sugar group in emphloin is probably attached through one of these hydroxyls.

Although the tannins are similar the kinos of the "Stringybarks" do not contain the glucoside emphloin, but in the leaves of some of them, *E. macrorhyncha* particularly, a glucoside, myrticolorin, occurs. It is a glucoside of quercetin and the sugar is glucose. It occurs in considerable amount in some species, and 8½ pounds in a dry condition was obtained from 100 pounds of leaves when these were treated by commercial methods. Myrticolorin ($C_{27}H_{28}O_{16} + 3H_2O = C_{15}H_{10}O_7 + 2C_6H_{12}O_6$) is a true dye material giving to mordanted cloth the usual colors of the quercetin glucosides, and could be obtained in any quantity if required. If raffinose be considered as allied to the glucosides, we find a similar substance in each of the large groups of eucalypts: raffinose from the group whose kinos contain eudesmin, and whose oils are rich in eucalyptol; emphloin from the "Ironbarks" and allied species; and myrticolorin, from species whose kinos consist of a tannin alone and whose oils contain phellandrene.

The comparative astringency value of the kinos of the "Ironbarks," when determined with potassium permanganate, is only about half that of the "Stringybarks" and allied species, although the tannins are similar. This is accounted for by the presence of the glucoside in the "Ironbark" kinos.

By the systematic investigation of numerous kinos from undoubted species, it has been determined that eucalyptus exudations, obtained from certain species, are more satisfactory for the pharmacist than perhaps any other astringent exudation. The best of these kinos do not gelatinize in tinctures under ordinary conditions, no matter how long they may be kept, and they require no corrigent; they are markedly astringent, readily soluble in alcohol, are not precipitated on dilution with water, and may be stored in a dry condition for an unlimited time without alteration. The kinos of *E. microcorys* and *E. calophylla* answer the above conditions; the former species, however, only yields kino in small amount and is thus difficult to collect, but *E. calophylla* exudes abundance of kino. This species is the "Red Gum" of West Australia, and its kino contains aromadendrin but not eudesmin.

Although it has been considered convenient to roughly classify the eucalypts into groups, yet the chemical constituents slowly graduate from one species to another. This is well illustrated with the tannins in the kinos. There appear to be three tannins in eucalyptus exudations, and these give distinctive differences with very dilute ferric chloride. Those kinos giving green and violet colorations gelatinize in tinctures, while those giving a blue coloration do not gelatinize. It is the predominance or absence of any one of these tannins in any particular kino that governs its rate of gelatinization. This rate may very well be determined by the aid of formaldehyde, a few drops of commercial formalin solidifying in twenty-four hours, an alcoholic solution of those kinos giving most markedly a violet coloration with ferric chloride, but acting less quickly on kinos containing the other tannins in larger amount.

The formalin test seems to be a reliable one for determining the gelatinizing properties of kinos, and it may be assumed that tinctures which do not form a jelly in four days under like conditions will not readily gelatinize.

A very interesting fact in regard to eucalyptus trees is that in the bark of several of them a large amount of calcium oxalate occurs. This salt does not appear to have been found in quantity in the bark of other plants belonging to genera which often occur as large trees, so that in this respect the eucalypts are peculiar. The crystals have not been found as raphides, but in well-developed microscopic monoclinic crystals, containing one molecule of water, a marked feature being the frequent occurrence of geniculate twins, with the twinning plane parallel to the basal plane of the crystal. These microscopic prisms are a constant feature of this salt in all the barks tested. The crystalline form and composition show a strong resemblance to the mineral *whewellite*. The percentage occurring in the barks of several species ranged from 16.66 to 5.1 per cent. Scientifically the occurrence of such large amounts is most interesting, as it enables a probable theory to be advanced to account for the formation of the shrubby forms of eucalypts, or "Mallees." Of the species containing over 8 per cent, only two have any pretensions to be considered as forest trees; the rest are "Mallees," and mostly have a thin smooth bark, which usually ranges in thickness from 1-10 to 1-5 inch. It is probable that these degenerate forms of "Mallee" growth have been brought about by the poisonous effect of the excess of the oxalic acid in the plant, and that the "Mallee" form is but a stage in the extinction of the species. The presence of the oxalic acid in these barks is usually associated with the tannins of economic value, and this result, taken with the presence of such large quantities of oxalate of lime, gives these barks considerable economic importance. The value of the "Mallet," *E. occidentalis*, for tanning purposes is well known, but the tannin of the "Gimlet," *E. salubris*, seems to be even better, although it is not present in such large quantity. An analysis of the bark of *E. salubris* gave 18.6 per cent of tannin; this makes an excellent tanning extract, which was found to be but slightly decomposed when evaporated to dryness on the water bath, so that a slight reduction in pressure would serve for perfect evaporation with this extract. The tannin is light in color, astringent, and acts on hide similar to the tannin of the "Mallet." The large amount of oxalate of lime in the bark residue after extraction makes it worth while to consider whether it could not be profitably extracted for the oxalic acid it contains. The value of the tannin extract should cover all expenses of collection, grinding, extraction, etc. Eucalyptus barks containing a large percentage of calcium oxalate are readily powdered when dry as they are very brittle.

Under ordinary conditions the eucalypts appear to assimilate the calcium oxalate first formed, but when the deposition increases faster than it can be absorbed, then the plant seems to lose this power of assimilation, and it becomes stunted in growth, and perhaps eventually disappears as a species. That this is so I have been able to show from the investigation of the bark of an individual forest tree, *E. oreades*. The living bark contained 1.37 per cent calcium oxalate, the thin ribbon-like bark shed from the outer portion of the same tree only contained 0.025 per cent, while in the thicker persistent bark at the base of the trunk none could be detected.

The chief interest to chemists lies in the remarkable variety of oil constituents of the various species; in the peculiarities and wide range of the kinos or astringent exudations, in the varying tannins from the barks and sugary products, in the large quantities of calcium oxalate in the barks of certain species, and in the presence of the glucosides. Such an abundance of chemical products existing in the several members of one group of trees points unmistakably to the fact that the genus is not of recent origin, and the knowledge that perhaps three-fourths of the vegetation of Australia consists of eucalyptus trees in one form or another, suggest the possibility of successful commercial exploitation in new directions. It is true that many of these chemical products have only been discovered in very recent years, and the knowledge of their existence has hardly reached beyond the outskirts of local conditions, where the spirit of enterprise mostly restricts itself to the few main productions of the continent.

The amount of chemical work still waiting to be done in connection with the eucalypts is considerable, and many problems yet remain to be solved. It is, too, to the furtherance of scientific effort and investigation into the unknown properties of this unique vege-

* Abstract from the Journal of the Society of Chemical Industry.

tation of Australia, that real progress in the development of these resources can best be brought about. Every successful effort will ultimately react in increased commercial activity, with profit to Australia, and to the world.

ENGINEERING NOTES.

A steel works is to be built in Muroran, in the northern island of Japan. It is expected that the work will be commenced about the end of this year, and that the company will be in working order and ready for operations in 1909.

The Bosphorus bridge linking Europe to Asia is a project that Sultan Abdul Hamid has long had under consideration. The last bridge was that built of boats by Darius for the use of his army long before the Christian èra. The plans for the Turkish bridge were accepted years ago, and call for short suspension spans between a succession of granite towers.

W. J. Cudworth (Engineering, June 14, 1907), gives the results of experiments made in an attempt to trace the causes of rail corrugation on the North-Eastern Railway. Neither from general considerations nor from the results of tests, analyses, and microscopic examination are any definite conclusions arrived at. The bulk of evidence, however, seems to show that the metal itself is not in the present case at fault. Rails on curves were no more liable to corrugation than those on straight track, and the nature of the ballast seemed to take no part; but there was a slight preponderance of roaring rails on down gradients. There has not been a single case of fracture of a roaring rail on this railway. The roaring rails were, in seven cases out of eight, mechanically harder than otherwise very similar smooth rails, and on the tops of the corrugations the metal was, as usual, hardest. It seems possible that the action producing the corrugations may be akin to the chattering of tools.

The rolling of a ship is always in excess of the slope of the wave at the point of inflection, according to V. Clemien in Comptes Rendus. Owing to the feeble resistance of the keel, the energy of a great number of successive waves accumulates on the vessel. The expression for the maximum amplitude of rolling contains in the denominator the coefficient N of decrease of artificial rolling in calm water. For a normal vessel, N lies between 0.008 and 0.03. It may be raised to 0.05 by lateral keels, or by water ballast in the case of small amplitudes. The author describes a device for bringing up N to any value short of unity, which automatically transforms the kinetic energy of oscillation of the vessel into heat. It consists of a heavy plate oscillating about a horizontal axis parallel to the keel and passing through the metacenter. The plate oscillates in a viscous liquid. Or a channel full of the liquid is bent into an arc of a circle described about the metacenter and is laid athwart the vessel below, with a heavy sphere rolling along it through the liquid. The plate or sphere takes up the rolling impulse, which is frittered away as heat. The author exhibited the model of a mail-boat weighing about 40 pounds, which when floated in water was brought to rest after two or three oscillations, N being 0.3.

Among the new continental locomotives may be mentioned one of recent construction which is designed for the Brunig Railroad line. Here the grades are very steep, and the rack-rail system is used. The present locomotive is a combination of the adherence and the rack-rail system and is used upon a track of 1 meter (39.4 inches) gage. Locomotive and tender are built together, and the machine has three driving axles. The middle axle is worked by the exterior horizontal cylinders as is the valve mechanism of the Walschaert pattern. Above each of the cylinders is another which operates a shaft carrying two pinions. The latter are geared with wheels mounted on an axle. Likewise mounted upon this axle is the pinion of the rack rail. When the locomotive works by adherence alone, the cylinders of the latter mechanism operate with free exhaust, but when using adherence combined with the rack-rail, these cylinders discharge into the cylinders of the rack mechanism. It is to be noted that this system was used upon a combination locomotive made by the Esslingen Works, of Germany, a few years ago. The dimensions of the cylinders are 0.380 by 0.450 meter (15.2 by 18 inches) for both adherence and rack systems. The driving wheels measure 0.910 meter (36.4 inches) in diameter and the distance between axle centers is 3.100 meters (10.2 feet). A diameter of 0.860 meter (34.4 inches) is used for the pinion of the rack rail. The locomotive has a boiler tested at 14 atmospheres and uses a grate surface of 1.30 square meters (14 square feet) giving a heating surface of 62 square meters (669.6 square feet). The weight of the locomotive empty is 31 (long) tons; in running order, 33 tons, with 3 tons of water and 0.9 ton of fuel. Upon the grades of the Brunig line, which are over 45 deg., the above type of locomotive is used to draw trains of 55 tons at the rate of 7 miles an hour. On a level, they will make about 30 miles an hour. The first locomotive of the present type was built in 1905.

ELECTRICAL NOTES.

The recent electrification of a French incline cable railway has resulted in a stated saving of 50 per cent in power expense over that when operated by steam. A buffer battery on the 500-volt direct-current line assists in maintaining an even voltage when starting and accelerating trains.

The British government is about to install a wireless telegraphy station on the Fiji Islands. This is a step toward the plan of linking all the British strategic points. Cables in time of war are liable to be cut by a hostile power, but aerial messages, even though interrupted, would prove valueless unless the enemy knew the cipher code.

Mr. Marconi is experimenting with Hertzian waves, with a view to using them for the transmission of power. He states that Hertzian waves are already employed for many purposes besides telegraphy in the British Navy. All of the larger ships are equipped with an apparatus by which the same waves employed for wireless communication are also used for the invisible transmission of power in the controlling and exploding of torpedoes.

An invention intended to nullify wireless messages in time of war is reported from Paris; Mr. Marconi while admitting the possibility of such an invention, points out that whereas the present cables might easily be cut with a few blows, it would require the erection of a large plant to nullify the wireless service, and the invention has yet to be thoroughly tested. Its discovery, however, he adds, is a valuable contribution to the wireless principle.

In a recent thunderstorm lightning twice struck the Singer Building in lower Broadway, during an interval of five minutes. The first bolt was in the form of a ball of fire, which struck the dome and then darted down the southern side of the structure for eighty feet or more, in the form of a streak of fire, disappearing long before it reached the ground. The scaffolding was evidently ignited by the charge, for a bright light glowed there for some minutes before it was extinguished by the falling rain. The second discharge struck the flagpole, and is supposed to have split it. It appeared as a flash that lighted up the flagpole as it hit the ball on the top. It has not been ascertained whether any damage was done to the steel work or not.

In order to illustrate the importance of wave-shape in connection with power transmission, C. F. Holmboe mentions the following case in Elektrotechnische Zeitschrift, which came under his observation. A 200-kilowatt motor-generator set, consisting of a continuous-current motor coupled to a three-phase generator, was employed to transmit power at 5,000 volts to a precisely similar set at a substation 8 kilometers away, where the three-phase current was transformed into continuous current. The full-load efficiency of either set was 84 per cent, and the power-factor with suitably adjusted exciting current was practically unity. After a time the first motor-generator set was replaced by a steam-driven three-phase alternator of different construction, giving a different form of wave. The efficiency of the substation set was found to have dropped to 79 per cent, and it was found impossible to adjust the power-factor to unity (it fluctuated between 0.91 and 0.98). The great loss of efficiency was due to the increase in the hysteresis and eddy-current losses occasioned by the presence of a resultant third harmonic. The reduced efficiency of the substation set, together with the increased loss in the line due to the reduction in the power-factor, represented a serious pecuniary loss to the supply company.

New applications of the Thomson process of electric welding are described in the Electrical Times. The surfaces of metal plates have points or projections formed on them, which enable them to be welded together by causing local heating when placed between the clamps of the welding machine. In this way small pulleys are made from stampings on the machine described. Another method of welding thin material consists in causing the edges, when heated, to be turned up against each other, and then hammering or pressing the upturned portion down against the surface of the material. Steel bands varying from ⅜ inch to 1¼ inch wide by No. 20 to 27 gage are welded in this manner on an automatic machine at the rate of 350 to 600 welds per hour. Hollow-handled cutlery is made by welding the handle, which is drawn from a sheet, to one side of a specially-shaped bolster, the blade being welded to the other side. Two hundred and fifty to three hundred welds are made per hour, the welding machine being operated by a boy. An advantage of the welded joint is that the plating liquid cannot enter the hollow handle and corrode the metal. Electrically-welded wire netting is made by automatic machinery in which the wires are fed downward from reels placed at the top, the cross-wires being fed from another reel at the side and cut to the length required. A number of welders, corresponding to the number of vertical wires, then weld the wires together where they intersect, and the operation proceeds automatically.

Automobile crankshafts are made by welding the two central portions, which are drop forgings, to straight rods consisting of drawn steel shaped to about the finished size.

SCIENCE NOTES.

Valuable photographs and thousands of dollars' worth of official data gained by the International Boundary Surveyors during the summer's work delimiting the Alaska line have been lost by the upsetting of a canoe in the Bradfield River. Five men narrowly escaped with their lives. The work may have to be done all over again.

A century ago, when whalebone was worth no more than 10 cents a pound, few vessels brought any home. From 1844 to the outbreak of the civil war the output averaged about 2,800,000 pounds annually, the greatest for one year being 5,692,300 pounds in 1853, and the price increased to $1 a pound. Since 1860 there has been a steady decrease in the output. In 1906 the average price paid for whalebone was $4.50 a pound.

According to Dr. von Holberg, Berlin, who has made a special study of the products of countries where the rainfall is scant and has just returned from visiting the Southwest, the people of Texas, New Mexico, and Arizona should be making millions of dollars every year out of growing dry land olives, figs, and dates. Parts of Texas now worthless and deemed only a barren waste, could be made to yield handsome profits if the rocky soil were planted with the chemlali or dry land olive that flourishes in northern Africa, and out of which the choicest olive oil is made. The United States is a heavy consumer of olive oil and imports its entire supply, which could just as well be produced at home.

Prof. Koch has published an official report of his investigations, carried out in Central Africa, into the origin and treatment of "sleeping sickness." His investigations showed that the *Glossina palpalis* fly, which causes the "sleeping sickness," subsists on the blood of reptiles and animals, and cannot live without it for over three or four days. The microscope showed that the blood sucked by the flies was chiefly that of crocodiles. The professor, therefore, recommends a bounty on crocodile eggs in order to encourage the natives to exterminate them. This, it is added, will be comparatively easy, since the crocodiles have certain well-marked breeding grounds in the Nyanza district, where the eggs can easily be collected. Prof. Koch also suggests clearing away the timber around the watering places near the forts and villages, where the natives gather; because the flies cannot endure sunlight and seek the dark, damp undergrowth.

With the aid of apparatus specially designed for the examination of the chemical changes brought about in gases by the influence of the light emitted from a mercury lamp, D. L. Chapman, S. Chadwick, and J. E. Ramsbottom studied the conversion of oxygen into ozone, the interaction of carbon monoxide and oxygen and the decomposition of carbon dioxide with a view to ascertaining the effect, in each case, of the presence of varying amounts of water vapor; the alteration of pressure being used to follow the course of the change. With mixtures of carbon monoxide and oxygen, the velocity of change of pressure is independent of the content of water vapor, but the yield of carbon dioxide increases and that of ozone decreases with increase of moisture; since carbon monoxide is not affected by ultra-violet light, it is probable that the first chemical effect of the light is the decomposition of the oxygen molecules into atoms, which then combine either with each other to give ozone or with carbon monoxide. A noteworthy observation is the stability of ozone toward ultra-violet light in presence of oxides of carbon. The decomposition of carbon dioxide by ultra-violet light takes place only when the gas is quite dry, its amount being about 3 per cent at ordinary pressure and 46 per cent at 36 millimeters pressure. These results show that, in a photochemical reaction, the position of equilibrium is not independent of the catalyst, so that the latter (moisture) exerts a marked influence in determining the mode of distribution of the energy among the molecules of the reacting substances.—Chemical Society Journal.

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